SPECIAL DATA COMMUNICATIONS GUIDE P.21

IEEE

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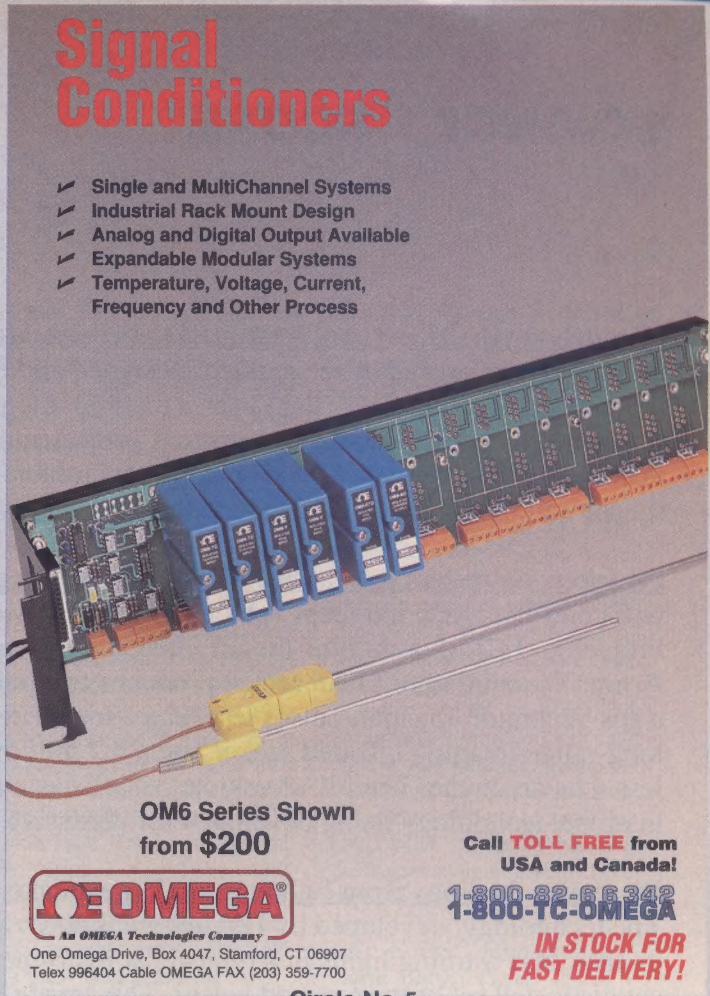

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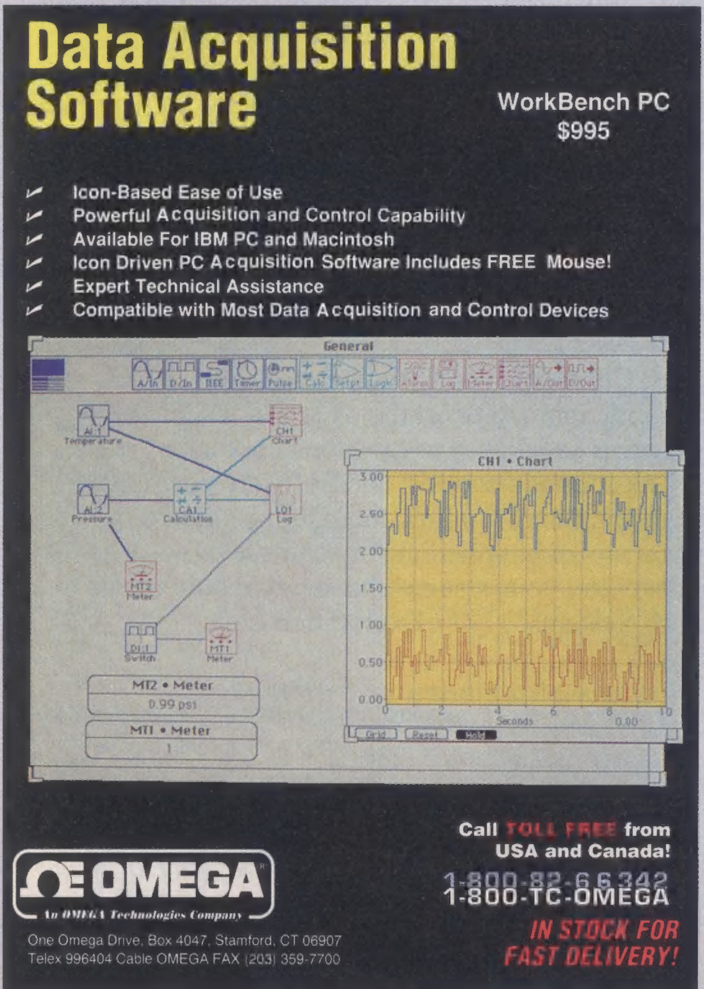

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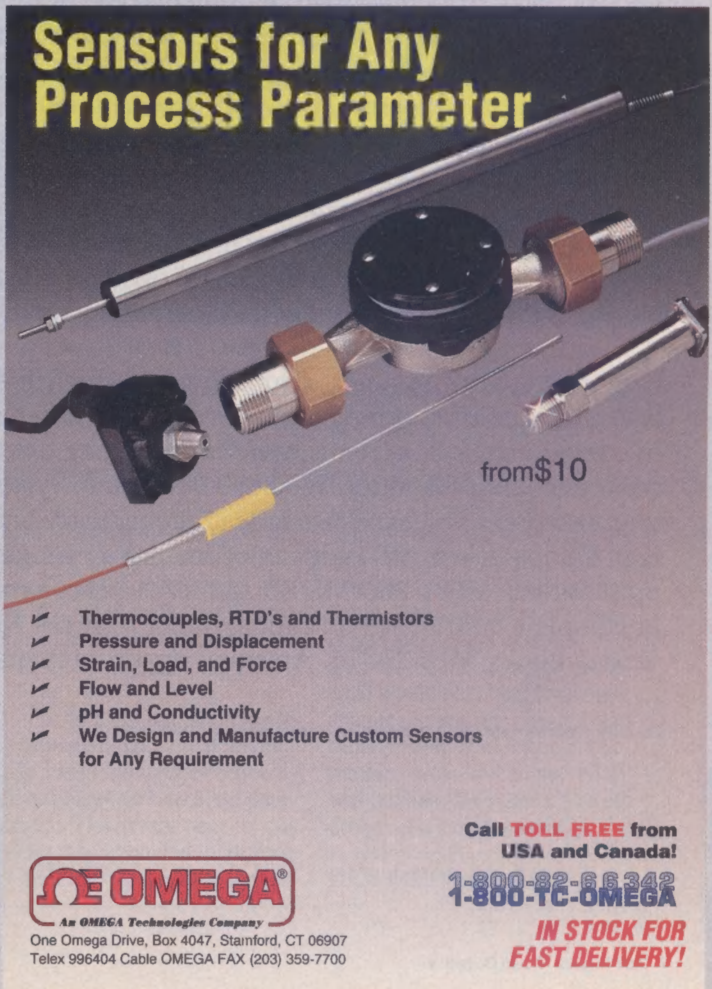

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Pilots flying the U.S. Navy's F/A-18 Hornet aircraft have a new navigational aid to help them in smoke, haze, darkness and adverse weather. Designed and built by Hughes Aircraft Company, the Thermal Imaging Navigation Set (TINS) uses a thermal imaging sensor to provide pilots with a television-like image of the terrain ahead. The image is projected onto a head-up display for night viewing or in poor visibility. TINS consists of four weapon replaceable assemblies including a forward-looking infrared sensor unit that detects and converts infrared energy into an electronics signal.

A rocket engine less than an inch long and weighing only 3.5 grams (about a tenth of an ounce) will control a space intercept vehicle. The engine was designed for the Lightweight Exo-Atmospheric Projectile (LEAP), a state-of-the-art intercept device under development by Hughes for the U.S. Army. The miniature LEAP rocket produces one pound of thrust by expelling hot gas, produced in a gas generator, in small pulses less than a millisecond in duration. The projectile also includes a long-range imaging infrared seeker and a 4.2 million instructions-per-second computer that weighs less than an ounce. The LEAP vehicle, which has no warhead, is the smallest and lightest-weight intercept technology being developed for defensive applications.

Display technology from fighter aircraft may make driving easier for wearers of bifocal eyeglasses. The technology, developed by Hughes and known as Virtual Image Display, replaces the speedometer, gauges, and warning lights in a typical car instrument panel with a projected image created by a sophisticated set of mirrors and lenses. This image appears to be behind the dashboard, approximately six feet away from the driver, eliminating the need to shift from distance vision to near vision when reading the instrument panel. Drivers with bifocals may be able to drive and read the instruments without their glasses.

An improved sight stabilization system will significantly increase first-round hit probability for tank gunners. The two-axis stabilized head mirror for the U.S. Army's M1A2 Abrams tank is under development at Hughes. Current M1 tanks are equipped with a single-axis stabilized head mirror, which limits the gunner's ability to accurately sight and fire on moving targets when the tank is also moving. The new system is part of the Army's planned improvements for the M1A2. Hughes also produces the laser rangefinder and thermal imaging system for the current M1 tank.

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Newslog

JUNE 12. Researchers at Japan's **Nippon Telegraph & Telephone Corp.** and **Rutgers University,** Piscataway, N.J., said they had developed optical amplifiers that boost the signal from a laser more than 1000 times at 1.3 μm. The amplifiers, which use fluoride glass fibers treated with the rare earth praseodymium, can be fitted to existing systems. They promise to cut costs since they eliminate the need to convert light into electricity and back again in the course of boosting a signal.

JUNE 12. Motorola Inc., Schaumburg, Ill., said it won a key contract to supply **Ford Motor Co.,** Dearborn, Mich., with microcontrollers for engine and transmission control for all its vehicles. The companies will collaborate in developing the device, which will be a modification of Motorola's 88000 reduced-instruction-set computing (RISC) chip. Ford, the first car manufacturer to commit to a RISC chip, expects to place the devices in 6 million vehicles annually, beginning in the mid-1990s.

JUNE 14. IBM Corp. said it would be the first to produce the next generation of computer memory chips; full-scale production of its 16-Mbit chips will begin by year-end.

JUNE 18. Eureka, Europe's largest technological research program, celebrated its fifth birthday at The Hague in the Netherlands. Over 3000 organizations from 19 European countries are currently participating in 500 Eureka projects worth over 8 billion ecus (US $9 billion).

JUNE 18. Wang Laboratories, Lowell, Mass., said it joined with **IBM Corp.** in a marketing alliance that calls for IBM to invest US $100 million in Wang and for Wang to convert its computer image-processing software to run on IBM PCs, workstations, and minicomputers. Wang will also market the IBM desktop computers under its own label and resell IBM minicomputers under the IBM name.

JUNE 21. AT&T Co. and Hong Kong-based **Hutchison Telecommunications Ltd.** announced a joint venture that will expand AT&T's services by bringing Hong Kong, China, and Macao under its existing Easy-Link Services International network. To be called Hutchison-AT&T Network Services, the venture involves a variety of electronic mail and facsimile services. AT&T's move into Hong Kong comes just six months after it acquired Western Union Corp.'s electronic mail and Telex services.

JUNE 25. IBM Corp. said it had formed an alliance with **Lotus Development Corp.,** Cambridge, Mass., that calls for IBM to market Lotus programs for electronic mail and local-area network applications. IBM also said it would license the Objectivision program of software publisher **Borland International Inc.,** Scotts Valley, Calif. IBM will use the program, which makes designing PC programs easier, with its new OS/2 2.0 operating system.

JUNE 25. Nissan Motor Co., Tokyo, said it will introduce by 1993 electric cars using batteries that fully recharge in 15 minutes. That compares with 2 hours for the Impact electric car that **General Motors Corp.,** Detroit, Mich., plans to bring out in the mid-1990s, and about 8 hours for a minivan Detroit's **Chrysler Corp.** also expects to sell by the mid-'90s. The range of all three electric cars on one charge will be the same: about 200 km.

JUNE 25. AT&T Co. said it had applied to the **Federal Communications Commission** for permission to test a new network for pocket-sized radiophones. By using radio channels for which AT&T already holds licenses and now uses for maintenance tests, the system could relieve crowding on the cellular and regular mobile radio frequencies. If the FCC approves the tests, AT&T could start competing directly for local phone services, something it has not done since its breakup in 1984.

JUNE 25. Brazilian President Fernando Collor won a political victory over the opposition party with the passage of a law by the House of Representatives ending controversial protection for Brazil's information technology industry, beginning in October 1992. The law will permit Brazilians to import microcomputers and fax machines and allow foreign companies to produce any information technology they wish in Brazil.

JUNE 28. Intel Corp., Santa Clara, Calif., said the **Federal Trade Commission** (FTC) had begun an antitrust investigation into its business practices. The company said the FTC had requested documents from a case under arbitration between Intel and **Advanced Micro Devices Inc.,** Sunnyvale, Calif., a former partner, but Intel denied any anticompetitive practices to achieve or protect its position as the leading manufacturer of microprocessors used in IBM-compatible PCs.

JULY 2. NASA said it will spend US $20 million in three years for a mission sending astronauts to install corrective lenses on the **Hubble Space Telescope.** The $1.5 billion instrument, sent into space last year, was discovered to have spherical aberration in its main mirror.

JULY 3. IBM Corp. and **Apple Computer Inc.,** Cupertino, Calif., said they will jointly create advanced software and computers. The rivals plan to develop: an advanced operating system for use by both companies and for sale to others; products that will help Apple Macintoshes share information with IBM machines; and a variant of IBM's version of Unix that will run programs written for the Macintosh.

JULY 9. Groupe Bull SA, Paris, said NEC Corp. of Japan would acquire 4.7 percent of the state-owned computer maker in exchange for a 15 percent stake in Bull's international affiliate, Bull HN. Although French Prime Minister Edith Cresson had earlier expressed concern that NEC would gradually gain control of Bull, the Government allowed the company to make the swap. NEC currently supplies the largest computers sold under the Bull name.

JULY 9. DSC Communications Corp., Plano, Texas, a manufacturer of telephone and call-routing computers, said a defect in 3–4 lines of computer code had apparently disrupted local phone service for 10 million customers around the country since June 26. Recent flawed software upgrades sent a flood of erroneous messages when a telephone company computer encountered routine maintenance problems. The **Federal Communications Commission** said a special team would investigate.

Preview

AUG 11. By this date, the **U.S. National Institute of Standards and Technology** (NIST), Gaithersburg, Md., plans to apply to the **U.S. Patent Office** for a new Federal standard that would permit electronic authentication of documents and access systems. The planned digital signature standard would also help to protect against computer viruses and other forms of electronic tampering. After the filing, NIST will publish the standard so its design can be examined.

COORDINATOR: Sally Cahur

AUGUST 1991 Volume 28 Number 8

IEEE SPECTRUM

FOCUS REPORT

Linking computers is no longer the main point of data communications. Finally, people are at the fore—wanting access in real time to their co-workers' data, images, and audio-video presentations. Worldwide demand for these multimedia transmissions will open up dramatically in the next few years. New standards specify 50–150-Mb/s local-area networks (LANs), well above the 10 Mb/s of most LANs today. Public networks are poised to tie it all together with packet switching that conforms to broadband integrated-services digital network—an emerging set of recommendations from the International Telegraph and Telephone Consultative Committee.

Rabbit Software Corp.

AWARDS

Among the 20 recipients this year of the IEEE's annual awards for technical achievements in their fields are experts in performance modeling, optoelectronic devices, CMOS, and image sensors.

Cover: Astronaut Jerome (Jay) Apt, mission specialist on the STS-37 space shuttle mission last April, moves along a yellow beam on a tether shuttle—one of the position-translation devices that could be the harbingers of hardware to be used during activity outside the U.S. Space Station Freedom. See p. 18.
Photo: NASA

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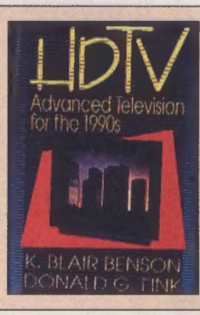
Books

HDTV on the fly

James E. Carnes

At a time when most high-definition television (HDTV) professionals are reluctant to use anything but pencil to make notes on developments in their constantly changing field, I was startled to see a hardcover book on the subject. Could it be that someone was poking fun at this very fluid situation?

HDTV: Advanced Television for the 1990s. *Benson, K. Blair, and Fink, Donald G. McGraw-Hill, New York, 1991, 350 pp., $39.95.*



A look at the authors' names changed my mind. How appropriate that two of the most distinguished experts in this field—Don Fink and the late Blair Benson—have written the first in what I'm sure will be a long line of books on HDTV.

Writing a book on HDTV in 1990 must have been daunting. To be sure, certain sections were outdated, probably before the ink was dry (even Chapter 14, which purports to be the "late news," is mostly out of date). But that does not nullify the value of this book for both veterans and newcomers.

The newcomer will find the book an excellent tutorial, especially if he or she bears in mind that most of the systems described have been dropped or substantially changed. NHK's (Japan Broadcasting Corp.'s) Narrow multiple sub-Nyquist encoding (MUSE) and the David Sarnoff Research Center's advanced compatible television system (ACTV-I) are two exceptions.

The book opens with a good review of the promises and problems of HDTV, giving useful statistics on the global penetration of television. The authors address the important issue of compatibility and describe the outlook for all delivery modes: terrestrial broadcasting, cable, satellite, and prerecorded media (videotapes and disks).

Chapter 2 discusses techniques used in advanced TV systems, such as resolution improvement, time- and frequency-division multiplexing, bandwidth requirements, and channel augmentation. CCIR (International Radio Consultative Committee) sampling rates are discussed, but no mention is made of other common sampling formats.

The third chapter reviews the psychovisual aspects of HDTV, covering such topics as luminance and chrominance, spatial acuity, flicker perception, continuity of motion, and defects of interlaced scanning. The chapter is followed by an undergraduate-level review of digital operations in video systems, and can be skipped without loss of continuity for most readers. Omitted is any mention of common digital recording formats, such as D-1 and D-2.

Chapter 5 is a brief introduction to three-dimensional sampling and the 3-D spectra of video signals. Unfortunately, the coverage is cursory at best; much better explanations are found in the references.

Chapter 6, on compatibility in HDTV systems, focuses on channel-compatible systems, simulcast systems, and transcoding devices. It is followed by a good review of the development and parameters of the 1125-line HDTV system, which was originally developed by NHK and later modified by the Society of Motion Picture and Television Engineers Inc. as the 240M standard. All serious HDTV professionals should be familiar with the material in this chapter.

Chapter 8 reviews eight single-channel receiver-compatible systems; of these, only one—ACTV—has survived and is to be tested by the Federal Communications Commission (FCC). Three simulcast systems are also reviewed, as well as six augmentation systems in the next chapter (all of these six have been abandoned, however). Obviously most of the information in these two chapters is of historical interest only.

Chapters 10–13 are good reviews of HDTV equipment, including cameras, displays, tape recorders, switchers, and telecines. As mentioned before, Chapter 14 contains what was late-breaking news on advanced television systems, FCC rulings, and schedules.

This book is a good overview of the HDTV industry. Though much of it is outdated to some degree, it is surely in the vanguard of many more books on the subject. It is a "must" for anyone seriously or professionally interested in HDTV.

James E. Carnes (F) is president and chief operating officer of the David Sarnoff Research Center in Princeton, N.J., a contract research and development subsidiary of SRI International.

COORDINATOR: Glenn Zorpette

Recent books

Vector Control of AC Machines. *Vas, Peter,* Oxford University Press, New York, 1990, 332 pp., $98.

The Transputer Handbook. *Graham, Ian,* and *King, Tim,* Prentice-Hall, Englewood Cliffs, N.J., 1990, 200 pp., $33.95.

Calendar

Meetings, Conferences and Conventions

AUGUST

Sixth International Symposium on Intelligent Control (CS); Aug. 12–16; Key Bridge Marriott, Arlington, Va.; Alexander H. Levis, Department of Electrical and Computer Engineering, G. Mason University, Fairfax, Va. 22030; 703-764-6282.

International Symposium on Electromagnetic Compatibility–EMC '91 (EMC et al.); Aug. 13–15; Hyatt Cherry Hill, Cherry Hill, N.J.; Henry W. Ott, 45 Baker Rd., Livingston, N.J. 07039; 201-386-6660.

Neural Networks for Ocean Engineering Workshop (NN/OE); Aug. 15–17; Loews L'Enfant Plaza Hotel, Washington, D.C.; Patrick K. Simpson, General Dynamics–Electronics, 5011 Kearny Villa Rd., Building 70, Mail Zone 7202-K, San Diego, Calif. 92186-5310; 619-573-2417.

First International Conference on the Applications of Diamond Films and Related Materials (ED); Aug. 20–22; Auburn University Hotel and Conference Center, Alabama; Y. Tzeng, Department of Electrical Engineering, Auburn University, Auburn, Ala. 36849; 205-844-1869 or -2427; fax, 205-844-2433 or -1809.

Fourth International Vacuum Microelectronics Conference (ED); Aug. 22–24; Nagahama Royal Hotel, Shiga, Japan; Junzo Ishikawa, Department of Electronics, Kyoto University, Sakyo-ku, Kyoto 606, Japan; (81+75) 753 5325 or 5021.

Hot Chips Symposium (C); Aug. 26–27; Stanford University, Stanford, Calif.; Robert Stewart, Stewart Research Enterprises, 1658 Belvoir Dr., Los Altos, Calif. 94024; 415-941-6699; fax, 415-941-6699.

Workshop on the Future of Electronic Power Processing and Conversion (IA); Aug. 28–29; Kruger National Park, South Africa; W. Portnoy, Texas Tech University, Dept. of Electrical Engineering, Box 4439, Lubbock, Texas 79409-3102; 806-742-3533.

Region 10 Conference on Energy, Computer, Communication and Control Systems–Tencon '91 (C, COM, et al.); Aug. 28–30; Taj Palace Inter-Continental, New Delhi, India; K.R.S. Murthy, AT&T Bell Laboratories, Crawfords Corner Road, Room 2N-437, Holmdel, N.J. 07733; 908-949-4850; or H.L. Bajaj, B-101, Hillview Apartments, Vasant Vihar, New Delhi 110 057, India; (91+11) 360 412.

SEPTEMBER

Bipolar Circuits and Technology Meeting (ED); Sept. 9–10; Minneapolis Marriott Hotel, Minnesota; John Shier, 2800 E. Old Shakopee Rd., Bloomington, Minn. 55425; 612-853-3292.

Petroleum and Chemical Industry Technical Conference (IA); Sept. 9–11; Royal York, Toronto; Barry Wiseman, Reliance Electric Co., 5220 Creekbank Rd., Mississauga, Ont. L3W 1X1, Canada; 416-625-8112.

Third International Conference on Microstructures in Biological Research (ED); Sept. 9–12; Fort McGruder Inn and Conference Center, Williamsburg, Va.; Martin Peckerar, Naval Research Laboratory, 4555 Overlook Ave., Washington, D.C. 20375-5000; 202-767-3150.

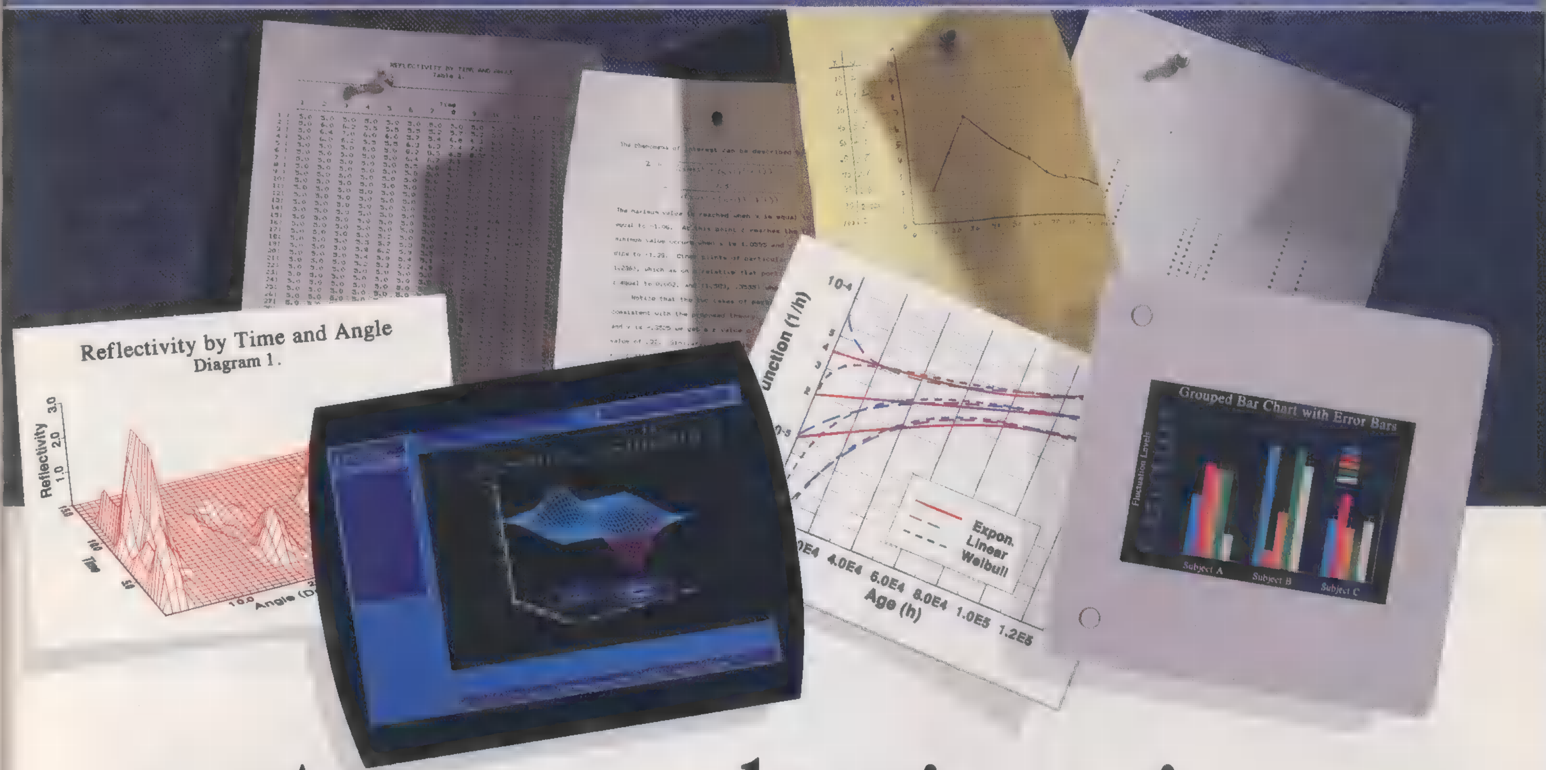
11th International Electronic Manufacturing Technology Symposium (CHMT); Sept. 16–18; Le Meridien Hotel, San Francisco; Bill Moody, 2529 Eaton Rd., Wilmington, Del. 19810; 302-478-4143; fax, 302-478-7057.

Philadelphia Permanent Magnet Meeting (MAG); Sept. 19; SPS Technologies, Jenkintown, Pa.; Y. Bogatin, 215-572-3579/3000, and B. Lorenz, 215-499-4050.

Seventh Multidimensional Signal Processing Workshop (SP); Sept. 23–25; Whiteface Inn, Lake Placid, N.Y.; John Woods, Computer and Systems Engineering, Rensselaer Polytechnic Institute, Troy, N.Y. 12181; 518-276-6079.

18th International Conference on Computers in Cardiology (COMP et al.); Sept. 23–26; Venice, Italy; Corso Stati Uniti 4, 35020 Padova, Italy; (39+49) 829 5702.

International Symposium on Gallium Arsenide and Related Compounds (ED); Sept. 23–26; Seattle, Wash.; L. Ralph Dawson, Sandia National Laboratories, Division 1144, Albuquerque, N.M. 87185; 505-844-5678.



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(Continued from p. 8)

Autotestcon '91 (AES et al.); Sept. 23–26; Disneyland Hotel, Anaheim, Calif.; Robert C. Rassa, Mantech Advertising Systems International, 150 South Los Robles Avenue, Suite 350, Pasadena, Calif. 91101; 818-577-7100; fax, 908-222-5816.

Fourth Annual International Application Specific Integrated Circuits Conference and Exhibit (IEEE Rochester et al.); Sept. 23–27; Rochester Riverside Convention Center, Rochester, N.Y.; Kenneth W. Hsu, Department of Computer Engineering, Rochester Institute of Technology, Rochester, N.Y. 14623; 716-475-2655; fax, 716-475-6879.

Industry Applications Society Conference (IA); Sept. 28–Oct. 4; Hyatt Regency, Dearborn, Mich.; William Moylan, Moylan Engineering Associates, 13530 Michigan Ave., Dearborn, Mich. 48126; 313-582-9880.

OCTOBER

International SOI Conference (ED); Oct. 1–3, Hyatt Regency, Beaver Creek Resort, Vail Valley, Colo.; Michael T. Duffy, David Sarnoff Research Center, CN 5300, Princeton, New Jersey 08543-5300; 609-734-2734.

International Joint Power Generation Conference–IJPGC '91 (PE); Oct. 6–9; Town and Country Hotel, San Diego, Calif.; M. Scalice, American Society of Mechanical Engineers, 345 E. 47th St., New York, N.Y. 10017; 212-705-7053.

37th Holm Conference on Electrical Contacts (CHMT); Oct. 6–9; Marriott Downtown Hotel, Chicago; Conference Registrar, IEEE Inc., 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3863.

20th Electrical/Electronics Insulation Conference–International Coil Winding Association Exposition (DEI); Oct 7–10; Sheraton Boston Hotel, Boston; Ron Sampson, 4250 Bulltown Rd., Murrysville, Pa., 15688; 412-733-8049 (O); 412-327-1796 (H).

22nd Photovoltaic Specialists Conference (ED); Oct. 7–11; Riviera Hotel, Las Vegas, Nev.; Howard E. Pollard, Ford Aerospace Corp., 3939 Fabian Way, M.S. G45, Palo Alto, California 94303-4695; 415-852-5131.

Fourth International Conference on Amorphous and Crystalline Silicon Carbide and Other III–IV Materials (ED); Oct. 10–11; Santa Clara University, California; Cary Yang, EECS, Santa Clara University, Santa Clara, Calif. 95053; 408-554-6814.

Seventh Biennial IEEE U.S. Activities Careers Conference: Change and Competitiveness and Careers (USAB); Oct. 10–11; Denver Radisson Hotel; William Anderson, IEEE-USA, Suite 1202, 1828 L St., N.W., Washington, D.C. 20036; 202-785-0017; fax, 202-785-0835.

International Conference on Computer Design–ICCD '91: VLSI in Computers and Processors (ED); Oct. 14–16; **Massachusetts Institute of Technology CAD Open House;** Oct 17; Royal Sonesta Hotel, Cambridge, Mass.; Dwight Hill, AT&T Bell Laboratory, 3D-446, 600 Mountain Ave., Murray Hill, N.J. 07974; 908-582-7766.

International Display Research Conference (ED); Oct. 15–17; Hyatt Islandia Hotel, San Diego, Calif.; Andras Lakatos, Xerox Corp., 800 Phillips Rd., Webster, N.Y. 14580; 716-422-9700.

GaAs Reliability Workshop (ED); Oct. 20; Doubletree Hotel, Monterey, Calif.; Anthony Immorlica, General Electric Co.,

Calendar

Electronics Laboratory, Electronics Park, Syracuse, N.Y. 13221; 315-456-3514.

GaAs Integrated Circuits Symposium (ED); Oct. 20–23; Monterey Sheraton Hotel, Monterey, Calif.; S. Kuntz, Courtesy Associates, 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-347-5900.

Military Communications Conference–Milcon '91 (COM); Oct. 20–23; McLean Hilton, Virginia; Fay Brady, Mitre Corp., 7525 Colshire Dr., McLean, Va. 22102; 703-883-6733.

Vehicle Navigation and Information Systems Conference–VNIS '91 (VT); Oct. 20–23; Hyatt Regency, Dearborn, Mich.; Mark K. Krage, General Motors Research Laboratories, Department 18, 30500 Mound Rd., Warren, Mich. 48090; 313-986-2976.

Workshop on Applications of Signal Processing to Audio and Acoustics (SP); Oct. 20–23; Mohonk Mountain House, New Paltz, N.Y.; James Kates, City University of New York, Graduate Center, Room 901, 33 W. 42nd St., New York, N.Y. 10036; 212-642-2179, fax, 212-642-2379.

Advanced Semiconductor Manufacturing Conference and Workshop (ED); Oct. 21–22; World Trade Center, Boston; Margaret Bachmeyer, 2000 L St., N.W., Suite 200, Washington, D.C. 20036; 202-457-9584.

Portland International Conference on Management of Engineering and Technology–Picmet '91 (EM); Oct. 27–31; Marriott Hotel, Portland, Ore.; Dundar F. Kocaoglu, Portland State University, Engineering Management Program, Portland, Ore. 97207-0751; 503-725-4660.

Eighth International Conference on Automotive Electronics (VT); Oct. 28–31; Savoy Place, London, England; Jane Chopping, Conference Organizer, IEE Conference Services, Savoy Place, London WC2R OBL, England; (44+1) 240 1871.

International Logic Programming Symposium (C); Oct. 29–Nov. 2; San Diego Princess, San Diego, Calif.; IEEE Computer Society Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

International Professional Communication Conference (IPCC'91) (PC); Oct. 30–Nov. 1; Sheraton World Resort, Orlando, Fla.; Daniel Plung, Westinghouse Savannah River Co., 1070 Silver Bluff Rd., Aiken, S.C. 29801; 803-642-4066.

Sixth International Symposium on Computer and Information Sciences (C); Oct. 30–Nov. 2; Bilkent University, Ankara, Turkey; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013.

13th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMB); Oct. 31–Nov. 3; Hilton at Walt Disney World, Lake Buena Vista, Fla.; Joachim H. Nagel, Department of Biomedical Engineering, University of Miami, Box 248294, Coral Gables, Fla. 33124; 305-284-2442.

NOVEMBER

International Conference on Computer-Aided Design–ICCAD '91 (ED); Nov. 11–14; Santa Clara Convention Center, Santa Clara, Calif.; ICCAD, 1730 Massachusetts Ave., Washington, D.C. 20036-1903; 202-371-1013.

Third Topical Conference on Emerging Technologies in Materials (ED); Nov. 17–22; Los Angeles Hilton Hotel, Los Angeles, Calif.; S.H. Gehrke, Department of Chemical Engineering, University of Cincinnati, Mail Location 171, Cincinnati, Ohio 45221-0171; 513-556-2766; fax, 513-556-3473.

DECEMBER

International Electron Devices Meeting (ED); Dec. 8–11; Washington Hilton Hotel, Washington, D.C.; Melissa Widerkehr, c/o Courtesy Associates Inc., 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-639-4990.

Ultrasonics Symposium (UFFC); Dec. 8–11; Hilton Hotel at Disney World, Orlando, Florida; Don Malocha, Department of Electrical Engineering, University of Central Florida, Orlando, Fla. 32816; 407-275-2414.

22nd Annual Semiconductor Interfaces Specialist Conference (ED); Dec. 11–14; Disney Village Resort, Orlando, Fla.; Steve Lyon, Department of Electrical Engineering, Princeton University, Princeton, N.J. 08544; 609-258-4635.

Power Semiconductor Devices Workshop (ED); Dec. 12–13; National Institute of Standards and Technology (NIST), Gaithersburg, Md.; David Blackburn, NIST, Building 225, Room B310, Gaithersburg, Md. 20899; 301-975-2053.

Recent Books

(Continued from p. 6)

Electronics Packaging Forum. *Morris, James E.*, Van Nostrand Reinhold, New York, 1991, 459 pp., $56.95.

Object-Oriented Databases with Applications to Case, Networks, and VLSI CAD. *Gupta, Rajiv*, and *Horowitz, Ellis*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 447 pp., $49.

Digital Telephony, 2nd edition. *Bellamy, John*, John Wiley & Sons, New York, 1991, 572 pp., $64.95.

Developing Software to Government Standards. *Roetzheim, William H.*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 478 pp., $37.

Frequency Transmission Systems. *Whitaker, Jerry C.*, McGraw-Hill, New York, 1990, 432 pp., $49.50.

PC Graphics With GKS. *Bono, Peter R.*, *Encarnacao, Jose L.*, *Encarnacao, L. Miguel*, and *Herzner, Wolfgang R.*, Prentice-Hall, Englewood Cliffs, N.J., 1990, 321 pp., $44.95.

OS/2 Notebook. Ed. *Conklin, Dick*, Microsoft Press, Redmond, Wash., 1990, 784 pp., $29.95.

Institutionalizing Expert Systems: A Handbook for Managers. *Liebowitz, Jay*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 166 pp., $28.

Electronic Materials. *Warnes, L.A.*, Van Nostrand Reinhold, Florence, Ky., 1990, 292 pp., $44.95.

Data Structures and Program Design in C. *Kruse, Robert L., et al.*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 525 pp., $42.

The Market and Beyond. *Fransman, Martin*, Cambridge University Object-Oriented Press, New York, 1990, 333 pp., $54.50.

Introduction to the Theory of Programming Languages. *Meyer, Bertrand*, Prentice-Hall, Englewood Cliffs, New Jersey, 1991, 447 pp., $50.40.

Electronic Data Interchange. *Kimberley, Paul*, McGraw-Hill, New York, 1991, 290 pp., $34.95.

Manprint: An Approach to Systems Integration. Ed. *Booher, Harold R.*, Van Nostrand Reinhold, New York, 1990, 612 pp., $42.95.

Non-Monotonic Reasoning. *Lukaszewicz, Witold*, Ellis Horwood, London, 1990, 328 pp., $79.95.

(Continued on p. 56C)

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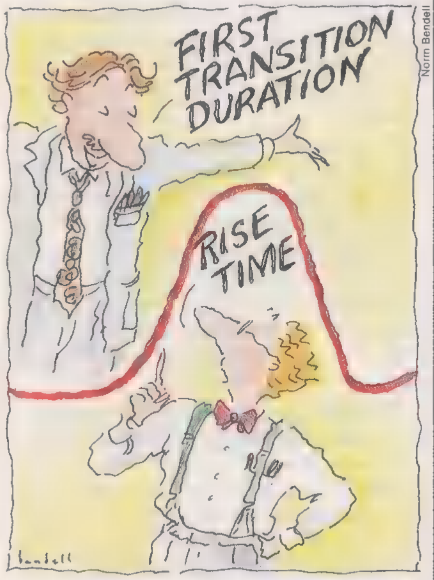
Technically speaking

Too accurate?

Sometimes the attempt to be accurate with engineering terms can fall on deaf ears. Such has been the case with *rise time* and *fall time*, terms that were purposely omitted because of this perceived lack of accuracy from the terminology for describing electrical pulses set out in 1977 in IEEE Standard 194. In their place, the standard anoints *first transition duration* and *last transition duration*, but little attention is being paid. *Rise time* and *fall time* remain in quite common use.

For example, none of the instruments made by Tektronix Inc., Beaverton, Ore., and Hewlett-Packard Co., Colorado Springs, Colo., makes use of the *transition duration* terms. The companies criticize the nomenclature as not being the way their customers talk. But recently, by a vote of the cognizant IEEE committee, the standard was amended to include the words in common use as alternatives, sort of.

Back in 1977, standards committee members concluded that *rise time* is ambiguous



when applied to a negative pulse. In this case, it could conceivably pertain to either the leading or trailing edge.

In contrast, *first transition* would clearly refer to the leading edge, and *last transition* to the trailing edge, whether the pulse were positive or negative. Furthermore, the committee reasoned that *time* in precise terms is a value at one point along a continuum, whereas the terms under consideration refer to a change in time or time interval; hence, the use of the word *duration* rather than *time*.

But even in engineering where, if anywhere, logic should prevail, the largely illogical matters of personal taste and familiarity enter in. Engineers are attached to *rise time* and *fall time* and are not about to give them up, according to informal surveys by Hewlett-Packard of its customers.

Both HP and Tektronix oscilloscopes read out pulse measurements as *rise time* whenever the transition is positive-going (even on the trailing edge of a negative pulse), and *fall time* whenever it is negative-going. It turns out the manufacturers also have logical reasons for using these terms. When automatic measurements are being taken, it may be difficult for the computer to differentiate between first transitions and last transitions.

More than unfamiliarity, the real objection to the standard terms is that they sound stilted and are awkward to say. Other terms in the standard contribute to this sentiment. *Proximal*, *mesial*, and *distal points* denote positions on the pulse nearest to, toward the middle, and farthest from the waveform baseline.

However, at least one of the instruments makers that prefers sticking with *rise time* and *fall time* has a product for the market that makes use of *proximal*, *mesial*, and *distal*. Stilted or not, this company obviously feels the terms contribute to a better understanding of what is being measured. That's not enough for one of its competitors, though, which declines to use these terms because, it says, its customers find the words too pedantic and pretentious for everyday use.

After debating the *rise time–fall time* issue—indeed, some members felt there was far too much discussion of what they regarded as a side issue and kept them from more important chores—the subcommittee on pulse techniques of the IEEE's TC-10 Waveform Measurement and Analysis Committee voted to include *rise time* and *fall time* as alternatives in the standard. However, it labeled the terms "deprecated." Translation: please don't use them.

The vote was 11 to 1, with one abstention. Said one member of the subcommittee: "We're trying to push people a little to get them to use more appropriate—and more accurate—terminology."

Another member, from an equipment maker, hoped the vote would put the issue to rest so the committee could get on to what he termed "real measurement issues." Besides, he said his company would continue to use *rise time* and *fall time*, deprecated or not, until its customer base told it otherwise.

COORDINATOR: Karen Fitzgerald
CONSULTANT: Anne Eisenberg, Polytechnic University

Innovations

Making multiprocessor programming smoother

Often the best way to deal with such compute-intensive problems as flight simulation, seismic data acquisition and signal processing, and radar and sonar data processing involves multiprocessing—which, however, is more easily said than done. It usually begs for programming specialists, especially at the debugging stage.

Programming a multiprocessing system becomes even rougher going when the intended user is a scientist rather than a software engineer. Typically, multiprocessors operate in a single-instruction, multiple-data (SIMD) mode, with a program being written and debugged for one processor, then copied to the other processors with the hope that all will operate smoothly. Debugging such a system calls for knowledge of the intricacies of the operating system, as well as the application.

Still, the application expert, rather than the programmer, is the target of CSP Inc., of Billerica, Mass. With the help of Multiprocessor Toolsmiths Inc., Ottawa, Ont., CSPI developed transparent multiprocessing for the RTS-860 Multiprocessor it had introduced earlier this year.

CSPI manufactures a family of vector processor cards (dubbed SuperCard) built around Intel Corp.'s powerhouse i860 microprocessor chip. These cards are combined in the RTS-860 to yield supercomputer-range performance—anywhere from 80 million floating-point operations per second to 2.56 billion (with 16 processors installed).

What's more, the multiprocessor system can be used for real-time problems because its operating system is a combination of Software Components Group Inc.'s pSOS+ real-time kernel and Multiprocessor Toolsmiths' Unison. Running on top of pSOS+, the Unison operating system provides Unix-compatible system calls for file and network access.

Multitasking/multiprocessing capabilities are performed by means of pSOS+. This kernel acts as a nucleus of supervisory software that enacts services on demand, schedules, manages, and allocates resources, and coordinates multiple asynchronous activities. This kernel runs on both a 68030-based central processing unit (CPU) controller also in the system and the SuperCard vector processors.

The pSOS+ kernel and Unison provide all of the control for multitasking within a single vector-processor board, as well as multiprocessing across multiple boards. Since pSOS+ and Unison run on both the CPU controller and the i860 vector processors, the processor hardware is completely transparent to user code. Unison also implements RPC (Remote Procedure Call), which permits the user to call a routine on the workstation host; the multiprocessor system works with Sun Microsystems Inc.'s workstations.

With CSPI's transparent multiprocessing, the user can do something not possible until now: debug an entire multiprocessing and multitasking application from a single window on a workstation. In effect, CSPI has automated the process of building the application so that the component programs can be shuffled easily to accommodate the number and types of processors available in the system.

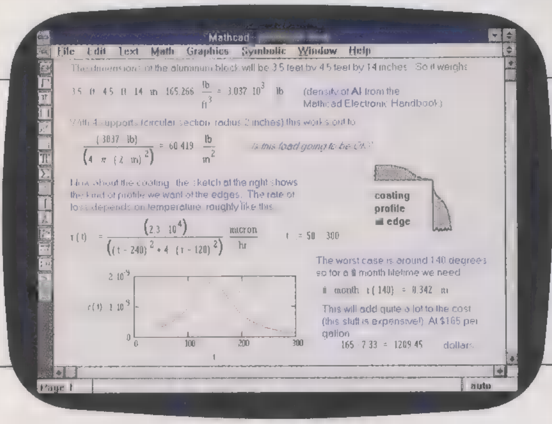
As a job is divided into individual tasks, those tasks can be placed on any processor with no change in code. And tasks may be moved from one processor to another to suit application needs. Interactive debugging is provided through a point-and-click user interface to CSPI's remote real time system and source-level debugger, called Remedy. This seems an apt name for a tool that can cure a lot of ills.

Remedy runs on the Sparc processor in the Sun workstations, and provides a full cross-development capability with network support. Implemented with a window and mouse-based interface, it is fully symbolic and handles multiple task debugging, dynamic task display, and task breakpoint. Essentially, Remedy provides the same level of debug facilities that would be available for a single processor. This goes a long way toward tailoring the programming of the multiprocessor system to the abilities of the scientist developing the application, rather than calling for the skills of a software engineer.

For information on the RTS-860 Multiprocessor, contact Geoffrey Cohler, CSP Inc., 40 Linnell Circle, Billerica, Mass. 01821; 617-272-6020; fax, 508-663-0150; **or circle 110.**

COORDINATOR: *Alfred Rosenblatt*

Calculations.



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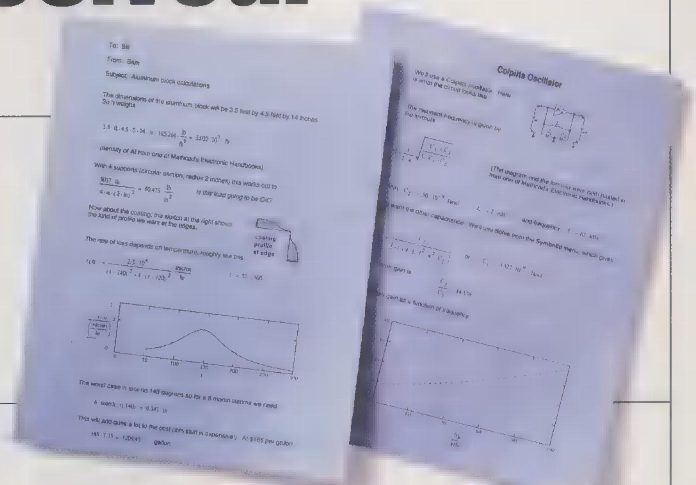

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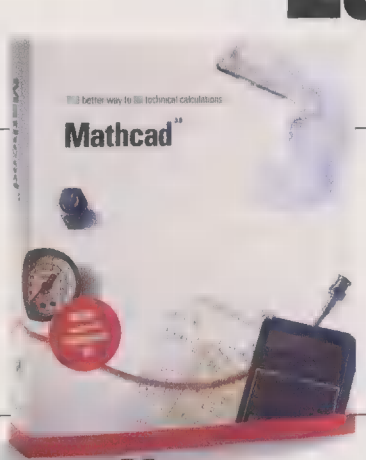

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Circle No. 12

Forum

Shedding light on radiation

The item on non-ionizing radiation [March, p. 28] caught my eye. It contains a number of perplexing statements either quoting or misquoting Bill Guy and J. Robert Ashley. First of all, it is perfectly appropriate to say that power lines, appliances, and even lightning radiate electromagnetic fields.

Furthermore, one does not need a 1000-km-high antenna to "radiate" 60-Hz fields. Indeed a 20-km grounded horizontal antenna can produce measurable signals at global distances (see the Communications Society *Transactions*' special issue on ELF [extremely low frequency], April 1974).

Ashley's statement that electric and magnetic fields near power lines are uncoupled is also inaccurate. The generated earth currents have tightly coupled E and H.

James R. Wait
Tucson, Ariz.

Author Ashley responds:
In IEEE Standards and in all the electromagnetic theory textbooks I have checked, the words *radiate*, *radiation*, and *electromagnetic fields* apply to traveling electromagnetic waves with frequencies ranging from fractions of a hertz to a terahertz. The electromagnetic field strength—watts per square meter—is found by calculating or measuring the Poynting vector, the cross product of the electric field and the magnetic field.

For a 60-Hz power line, the magnetic field flux lines encircle the conductors. The vector direction is essentially angular. For rural transmission lines, the magnitude is in the range of 1–10 microteslas. For urban distribution lines, the magnitude is in the range of 100–1500 nanoteslas. But the Denver, Colo., epidemiology studies of childhood cancer risk have raised unanswered questions about its correlation with conductor configuration in typical distribution lines. Thus, using a safety factor of 10, engineers can safely conclude that any 60-Hz magnetic flux density of less than 10 nT is insignificant.

If an electromagnetic wave were radiated away from a power line, the Poynting vector a few centimeters above ground would have an electric field component normal to the ground and the magnetic field vector would have a direction parallel to the conductors. This allows a simple measurement to determine if a power line radiates a *significant* electromagnetic wave. One measures to see if a magnetic field component parallel to the power line conductors is greater than 10 nT. (The much larger angular component is not transverse to the electric field and so does not contribute to radiation.)

I have done this for both transmission and distribution power lines. There is no significant radiation of electromagnetic waves by 60-Hz power lines. Similar theory and measurements give the same unequivocal results for appliances.

In contrast to the grounded antennas used for Project Sanguine as discussed in Wait's special issue, power lines do not have "generated earth currents." Maxwell's theory does tell us how to find the circulation of the magnetic field when the value of the time-varying electric field is known; but that is insufficient information to completely determine the magnetic field. Therefore, the electric and magnetic fields are essentially independent of one another.

Corrections

On p. 28 of the April issue, in the boxed statement, the phrase "the receiver next door" should have been "the receiver just down the block."

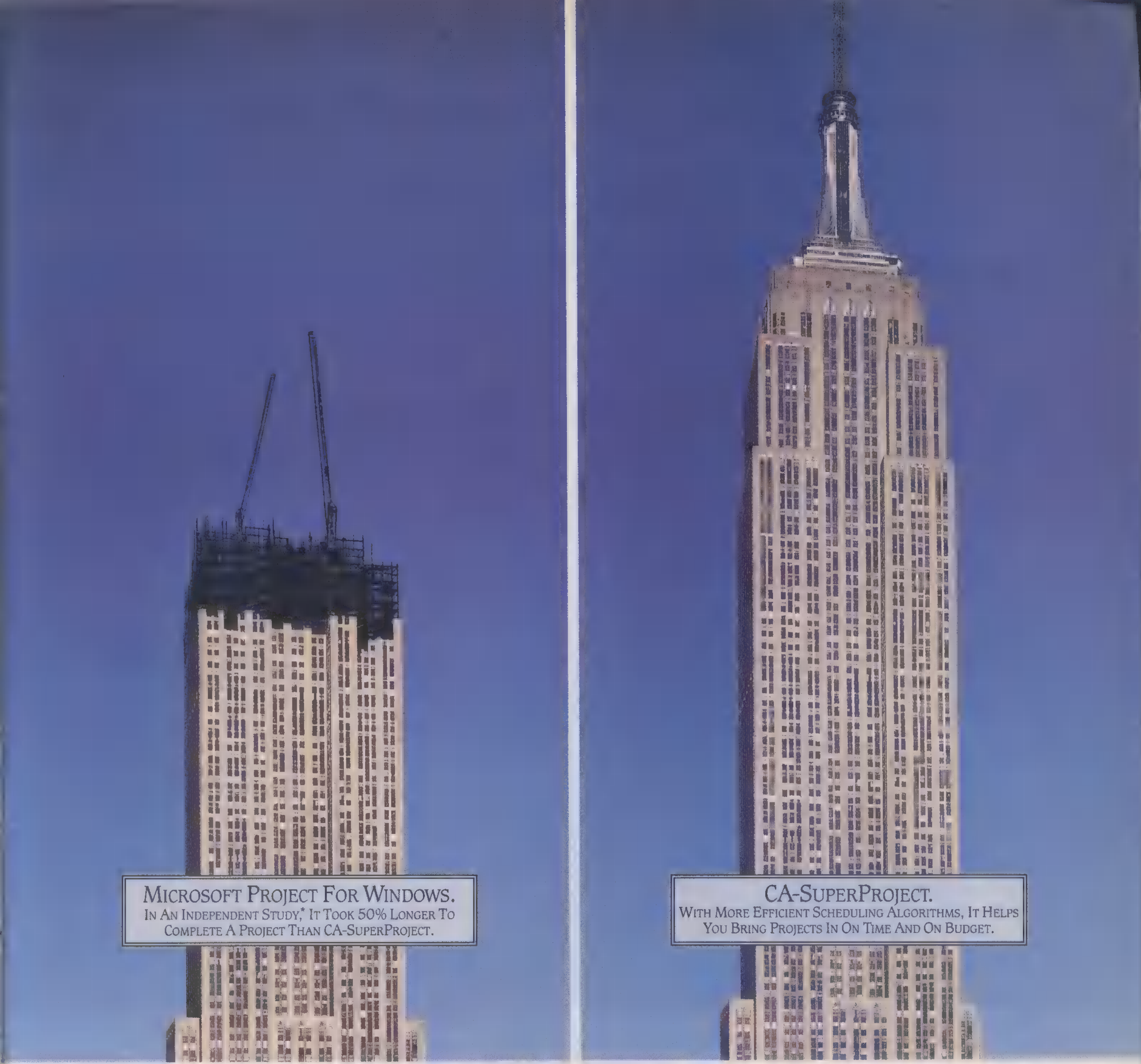
On p. 38 of the June issue, the last sentence of the caption of the diagram showing the AsiaSat 1 footprints should have read: "These are earth coverage contours of beam equivalent isotropically radiated power (EIRP) expressed in decibels above 1 watt. EIRP is the gain of a transmitting antenna in a given direction, multiplied by the net power accepted by the antenna from the connected transmitter."

On p. 42, it was stated that electricity in Korea comes predominantly from privately owned utilities. In fact, Korea Electric Power Corp. is a predominantly Government-owned enterprise (21 percent of its stock was sold in a public offering in 1989).

On p. 47, the German organization expected to bid on a high-speed rail project for South Korea should have been identifed as Inter City Express.

In the third column on p. 37 of the July issue, the contact for ordering the IDA report should have been the NTIS at 703-487-4650. —*Ed.*

Readers are invited to comment in this department on material previously published in *IEEE Spectrum*; on the policies and operations of the IEEE; and on technical, economic, or social matters of interest to the electrical and electronics engineering profession. Short, concise letters are preferred. The Editor reserves the right to limit debate on controversial issues. Contacts: Forum, *IEEE Spectrum*, 345 East 47th St., New York, N.Y. 10017, U.S.A.; fax, 212-705-7453. The Compmail/Internet address is ieeespectrum. The computer bulletin board number is 212-705-7308 and the password is SPECTRUM; for more information, call 212-705-7305.



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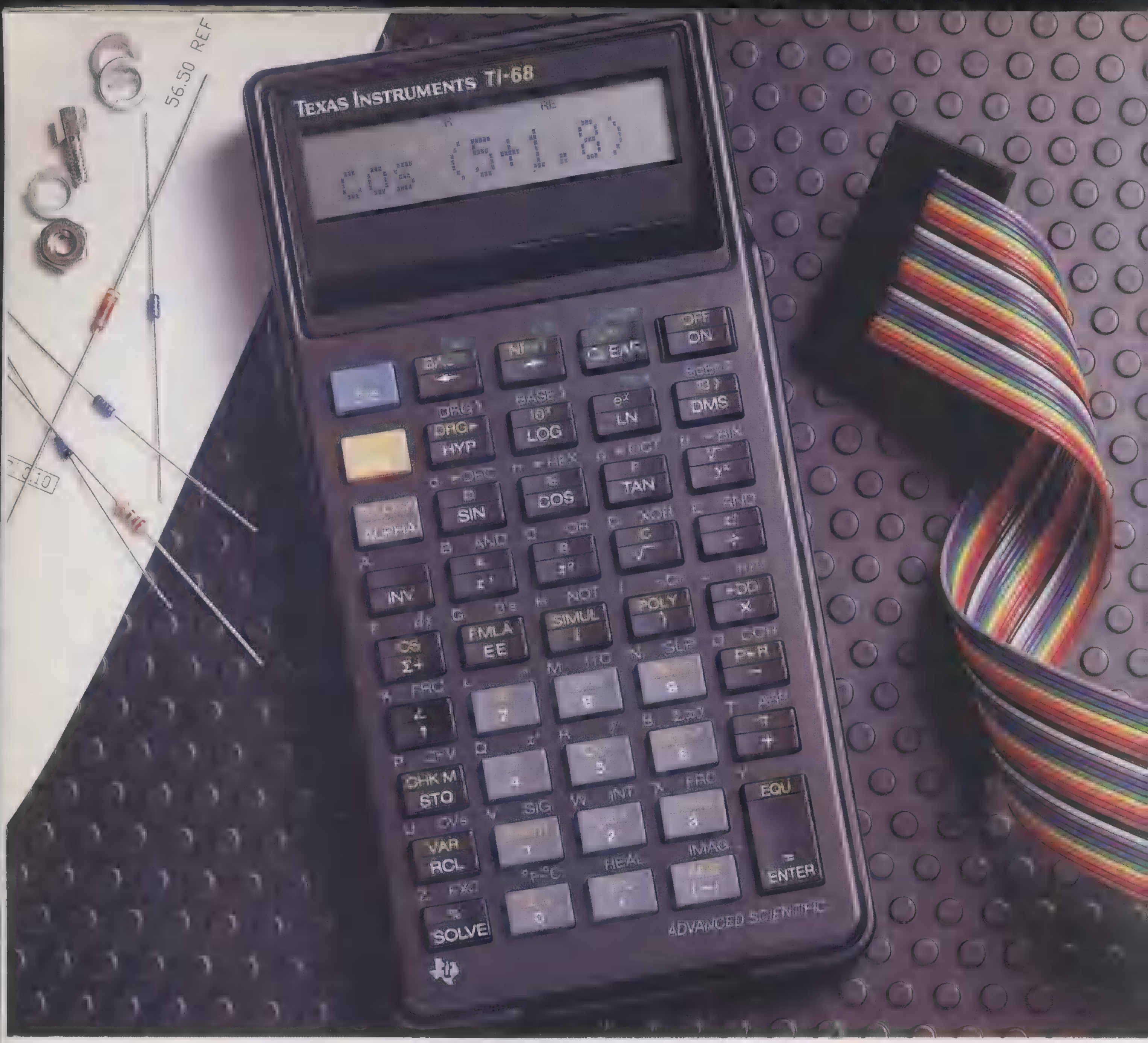
Circle No. 10



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TEXAS INSTRUMENTS

Circle No. 25

Spectral lines

AUGUST 1991 Volume 28 Number 8

Management under stress

In difficult economic times the rules and strategies of management change. When things are good, good will and kudos abound. When things are tough, criticism and paranoia raise their unpleasant heads.

The stiffness of competition has something to do with it. In sunshiny times, when business rolls in, the pressure to compete or to beat the competition in quality or quantity is low. In good times even the less qualified employees are seen as worthwhile contributors, even if they are less efficient.

However, with shrinking markets, or threatened market share, acceptable minimum performance levels rise, as do expectations for output, efficiency, and quality. To a point, the stiffening expectations have a positive effect. Even so, a few borderline performers may be shuffled out of their jobs into ones better matched to their abilities. But with extended pressure to compete, and, especially, to compete where success is not assured, managers often change their modes of managing.

They become more critical of sub-par performers—even openly critical. They do not commend hard work alone—it must be coupled with results. They avoid overpraising employees, particularly in writing. (It could make it painful and seemingly contrary when and if the employee has to be laid off.) They steel themselves against being overly "fatherly" to individual employees. (Engineering managers are not notable in the first place for their overt praise of their engineers.)

As managers deal with tight budgets, staff members, once flesh-and-blood contributors and important members of the "team," become "headcount." Some hardened managers use the term "bodycount"—a carryover from Vietnam, one supposes.

Eventually economic pressure can even bend the ethical structure of business.

Abraham Zaleznik, a Harvard Business School professor and author of *The Managerial Mystique*, writes that the greater competition brought on by deregulation in the United States during the 1980s caused a "looser moral conduct" of business people—even of professional managers with graduate degrees in business. He suggests that the new opportunities to make large sums of money by illegal and unethical means tempt many professionals who would not otherwise be lured.

The atmosphere resulting from deregulation, mergers, and acquisitions has left an indelible imprint on business in the United States. Engineers at AT&T Bell Laboratories reported experiencing a "year of turmoil and indecision" following the deregulation order before they could get back to serious and productive work. IEEE members in a 1988 poll suggested a decline in the level of dedication and creativity of the typical electrical engineer and a rising dissatisfaction with the job. More than 65 percent said they were less satisfied with their positions than they had been five years previously.

An erosion across the board of company loyalty—reaching well into the executive ranks—has followed the instability of employment by large U.S. companies.

There are no ready management solutions, as companies under duress drop entire product lines and as financially reeling municipalities discontinue worthy public services and social programs. But a sensitivity to the forces at work and the shifting strategies may be helpful to both employees and managers as they are buffeted by hard times.

Kudos

Two issues of *IEEE Spectrum* that garnered a high level of interest on the part of readers during the past several months were the October 1990 special issue "R&D: managing to be competitive" and the June 1990 special issue "Europower: looking ahead to 1992." Both were recently the recipients of additional recognition when they were named first-place winners in the 11th annual Society of National Association Publications award competition. The R&D issue was cited in its entirety by the judges for its in-depth, broad coverage "crucial to its audience" and "[demonstrating] attention to editorial and graphic detail." The judges, praising the cover design of the Europower issue, called it "bold and direct" and lauded its editorial impact.

Associate editor Karen Fitzgerald captured an Honorable Mention in the same competition for her article "Whistle-blowing: not always a losing game," in the December 1990 issue. The judges cited the author's realistic treatment of the fallout from whistle-blowing and called the decision to publish the article a "gutsy" one.

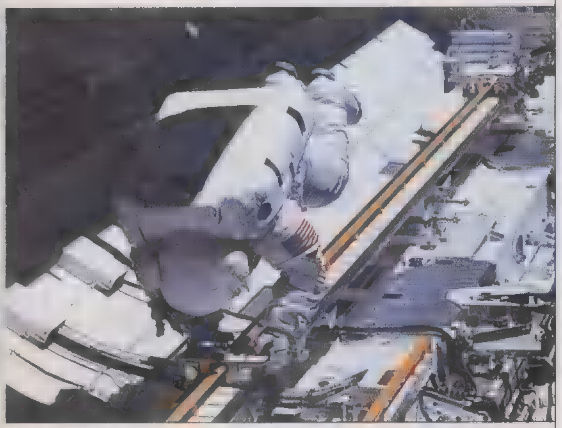
Meanwhile the American Society of Association Executives has selected the *IEEE Spectrum* Innovative Precollege Math and Science Competition as an award recipient in its "Associations Advance America Awards Program." The *Spectrum* competition challenged readers to nominate educators who developed innovative precollege (K-12) math/science programs. Descriptions of the best nominations were submitted to a jury of eminent educators, who chose six top programs in 1990. *Spectrum* will repeat the competition in 1991.

We're proud of the *Spectrum* staff members who contributed to these winning efforts.

Donald Christiansen

The United States in space

The U.S. space program's future is being argued in many domestic forums, with no clear consensus on direction



In May, ■ U.S. House of Representatives Appropriations subcommittee took an action that was unprecedented in the history of the U.S. space program: it killed President George Bush's request for US $2 billion to build the Space Station Freedom. Although most of the funding was restored by an overwhelming majority in ■ vote of the full House in June, the money was regained partially at the expense of unmanned scientific space exploration programs.

Together these two actions made urgent and public ■ major national ambivalence that has been haunting the U.S. space program for years: just what should the United States be doing in space? How much should it cost? And what does space exploration and technology return to the infrastructure of the nation ■■ ■ whole?

These are hardly new questions. But the House subcommittee vote explicitly demonstrated that at least some people in high places have grave reservations about continuing with the tradition of multibillion-dollar space projects. In announcing the original funding cut in May, Michigan Democrat Robert Traxler, chairman of the subcommittee for Veterans Affairs, Housing and Urban Development, and Independent Agencies of the House Appropriations Committee, declared: "We simply can no longer afford huge new projects, with huge price tags, while trying to maintain services that the American people expect."

For the first time, the gesture of killing the project gave those reservations force and prominence. The General Accounting Office has projected the overall cost of the space station to be $38.3 billion to build, and about twice that much more to operate into the 21st century. Although in the past members of Congress have grumbled, asked pointed questions, or criticized the wisdom of megaprojects in the U.S. space program, until now no group has outright eliminated the funding for a core project.

Ironically, the reinstatement of the $1.8 billion funding for the permanently manned space station has alarmed the space science community because of its interest in unmanned probes. Nearly half the reinstated money ($888 million) came out of budgets for a variety of unmanned projects for space science and applications, physics and astronomy, planetary exploration, aeronautical research and technology, and academic programs—repeating a pattern that has rankled the unmanned-project investigators since the earliest days of the space shuttle.

All this ambivalence has given the U.S. space program "an image problem," said Jerry Grey, director of science and technology and policy of the American Institute of Aeronautics and Astronautics, headquartered in Washington, D.C. "The continual cycles of reevaluation, rescoping, and review have damaged the space program, because they give the impression that everyone is fluttering around and doesn't know what to do," Grey said.

> 'The American public can no longer afford huge new projects with huge price tags'

CHANGED WORLD. There are strong international pressures to continue with the space station—because it is not purely a U.S. program. The threat to its survival in May angered Canada, Europe, and Japan, which have already invested about ■ quarter of the $8 billion dollars pledged to build laboratories and other hardware to attach to the space station.

These pledges underscore the changes in the international space picture from the 1960s, when the National Aeronautics and Space Administration (NASA) and the Soviet Union's space program had the heavens to themselves. Now several dozen nations boast their own space programs and satellites *[IEEE Spectrum*, Europower issue, June 1990, "Aerospace and defense," pp. 30–32; and Asiapower, June 1991, "Aerospace and defense," pp. 38–41]. Five entities have their own launch vehicles: the People's Republic of China, Europe, and Japan in addition to the United States and the USSR. All but Japan hire out launches; Europe's Arianespace company commands around 50 percent of the world's commercial launch business.

CHALLENGES AND TROUBLES. Meanwhile, there are domestic changes in the way the United States is pursuing space activities. NASA is not the only Government agency within the United States with a space program.

Since 1982, the Department of Defense (DOD) has spent more on space technology, development, and operations than NASA; by 1990 the DOD's annual budget for space was twice NASA's total budget. According to a Presidential Directive of March 1990, the United States' Space Exploration Initiative is to be a joint effort of NASA, the DOD, and the Department of Energy.

In addition, troubles have alloyed NASA's triumphs over the past five years. On the eve of Voyager 2's tour-de-force flyby of the planet Uranus in January 1986, seven space shuttle astronauts were killed in the Challenger accident. Last year—10 months after Voyager flew past Neptune—the primary mirror of the orbiting Hubble Space Telescope was discovered to have been shaped to the wrong figure.

On a lesser scale, ■ series of hydrogen leaks in the fuel lines from the shuttle's external tank to the orbiter grounded the entire shuttle fleet for five months. On the horizon are plans to launch the new weather satellite GOES-Next, in spite of design shortcomings.

This special report examines the U.S.

Trudy E. Bell Senior Editor
Karl Esch Contributing Editor

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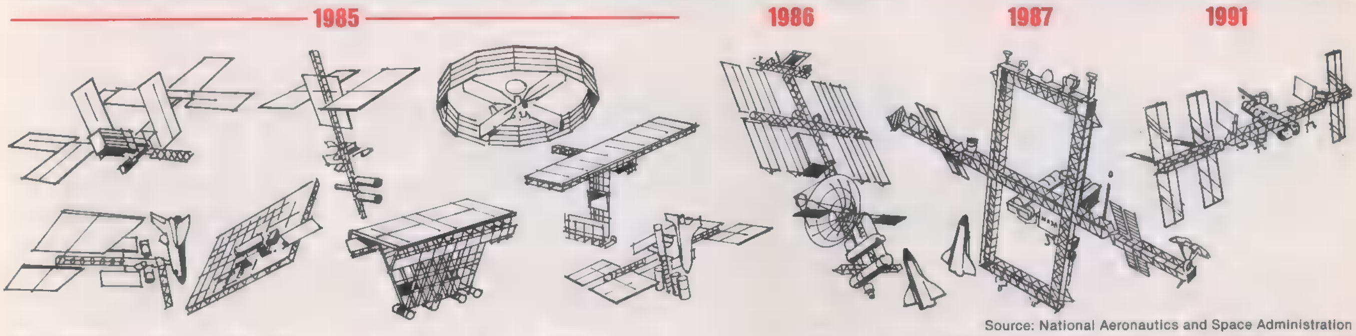
program in three contexts: its position internationally, its role domestically, and NASA's workings internally.

Some of the principal questions that it explores are:

- What does it mean for NASA to be simply a lead agency instead of the sole agency charged with implementing the U.S. space program?
- Are the types of technical and managerial troubles NASA has recently experienced different in quality and kind from the troubles it had during the Apollo era? How are the various pressures to which it is being subjected affecting its internal ways of doing business?
- Are there lessons from the experiences of other nations' space programs and their ways of overseeing projects and doing business that could be useful to the U.S. space program, and vice versa?



Source: National Aeronautics and Space Administration

The U.S.Space Station Freedom has gone through many different designs over the years, sometimes to accommodate more experiments or functions, sometimes to reduce costs. Eleven of the major ones considered by the U.S. National Aeronautics and Space Administration appear here. The eight on the left were proposed in 1985: clockwise from top left, they were known as the racetrack, the gravity tower, the spinning array, the streamline T, the planar, the delta truss, the bedspring, and the axial radial. By 1986, NASA had settled on one called the power tower. The next year, its preference changed to the dual keel design. The Phase I design that represents the latest selection is on the far right. The cost of the space station program from fiscal 1985 through fiscal 1991 has been $5.7 billion.

Design, estimated cost, and schedule changes for the U.S. portion of the space station

	Fiscal year budget						
Design	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
Configuration	8 early designs	Power tower	Dual keel	Phase I	Phase I	Phase I	Phase I
Number of laboratory modules	2	2	1	1	1	1	1
Number of habitation modules	1	2	1	1	1	1	1
Number of logistics modules							
Pressurized	2	1	2	3	3	3	3
Unpressurized	0	0	0	2	2	2	2
Number of U.S. crew members	6–8	6–8	6	6	6	6	6
Power generation, kilowatts							
Total	75	75	75	75	75	75	75
Allocation for users	N.A.	N.A.	N.A.	50	45	45	30
Number of satellites							
Polar orbiting	1	1	1	1	1	1	0
Co-orbiting with the station	1	1	1	0	0	0	0
Number of service facilities	1	1	1	0	0	0	0
Estimated cost							
1984 US dollars, billions	8.0	8.1	8.3	12.2	12.8	13.0	12.3
Then-year US dollars, billions	11.0	11.4	12.2	17.7	19.0	19.0	18.5
Schedule							
First launch	3/92	4/92	1/93	3/94	3/95	3/95	3/95
Man-tended capability	10/92	4/93	1/94	3/95	3/96	11/95	6/96
Permanently manned capability	1994	1994	1994	4/95	4/96	4/96	3/97
Assembly completion	N.A.	N.A.	N.A.	3/97	3/98	2/98	8/99
Number of shuttle flights	N.A.	N.A.	N.A.	16	19	20	29

N.A. = not available.

Source: General Accounting Office, *Space Station: NASA;s Search for Design, Cost, and Schedule Stability Continues*

Since 1985, the U.S. portion of the space station has increased in cost and the number of shuttle flights needed for full assembly, while decreasing in size, in the amount of power allocated to users, and in the number of service facilities. The National Aeronautics and Space Administration's estimated costs exclude costs for ground facilities, personnel, shuttle flights, and operations, which in 1991 the General Accounting Office estimated at US $19.8 billion. In fiscal 1987, when the number of modules decreased the total volume available to the U.S. station crew did not change dramatically. That same year, the space agency baselined a standard crew size of eight, but two spaces could be used by international partners. In fiscal 1991, the polar orbiting satellite was transferred to the space science program.

Other agencies, other goals

President Bush called for a multiagency manned mission to Mars, but many question Apollo-scale goals in the 1990s

On July 20, 1989, 20 years from the day that men first landed on the moon, U.S. President George Bush declared in a speech to the nation that U.S. efforts in space research and technology would be "a long-range continuing commitment."

Bush outlined three missions "...for the 1990s, Space Station Freedom,...for the next century, back to the Moon,...And then...a manned mission to Mars." In a May 1990 speech, he set the year of 2019 for the first landing of humans on Mars: "I believe that before Apollo celebrates the 50th anniversary of its landing on the Moon, the American flag should be placed on Mars." Together these three missions—the space station, the moon, and Mars—have come to be called the Space Exploration Initiative.

Bush asked Vice President Dan Quayle to lead the newly constituted cabinet-level National Space Council to determine "the necessary money, manpower, and material" and "the feasibility of international cooperation" and to "develop realistic timetables" for realizing the goals of the Space Exploration Initiative.

'NASA NOT A MONOPOLY.' One of Bush's concerns was the lack of much "high-level attention to space in the last 10–15 years," said an Administration official close to the National Space Council, who spoke on condition of anonymity.

Bush asked the Council to ensure a coherent national program in the civilian, national security, and commercial sectors, one that reached over institutional boundaries, the official said. "There's a lot of space expertise in this government—NASA [the National Aeronautics and Space Administration] doesn't have a monopoly," she observed.

The first of a series of policy decisions for the long-term Space Exploration Initiative was announced on March 8, 1990. Written by the National Space Council and approved by Bush, it noted: "The program will require the efforts of several agencies. NASA will be the principal implementing agency. The Department of Defense (DOD) and the Department of Energy (DOE) will also have major roles in the conduct of technology development and concept definition." The National Space Council was to coordinate the strategy among the three agencies, and "the Department of Energy will be added as a formal member of the National Space Council."

FORMALIZES THE RELATIONSHIP. Interagency cooperation is hardly new. Indeed, the 1958 National Aeronautics and Space Act, which founded NASA, stipulated in Section 102 (c) (8) that the nation should pursue its air and space goals by making "[t]he most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment."

In the 1950s and 1960s, NASA teamed up with the old Atomic Energy Commission (subsequently the Department of Energy) to explore nuclear rockets and nuclear electric propulsion technology for lengthy space voyages.

> 'NASA doesn't have a monopoly on space expertise'

NASA's earliest launch vehicles came from the DOD, and the space shuttle itself was designed and developed to meet Air Force requirements. Similarly, NASA and the Air Force have met periodically in a coordinating body known as the Space Technology Interdependency Group, which promotes joint R&D programs and fosters coordination between technologists in the two agencies.

Moreover, the long-standing SP-100 space nuclear reactor program has been a joint effort among NASA, the DOD, and the DOE.

The 1990 Presidential directive, however, "formalizes that relationship and makes the DOE an official player in the space business," said Fenton Carey, special assistant for space to Energy Secretary James D. Watkins.

Carey's charter is to create an office of space for the DOE "by October 1 or so" with 20–30 people responsible for policy, long-range planning, budgeting, and technical oversight of existing and emerging programs, he said.

Both the DOD and the DOE have built up expertise in space-related technologies in which NASA has not maintained leadership, said Stewart Nozette, a technical evaluator for the Synthesis Group. The group, led by Lieutenant General Thomas Stafford (U.S. Air Force, Retired), was appointed by Quayle and NASA to assess alternative approaches for implementing the Space Exploration Initiative. Its report, *America At The Threshold*, was presented to Quayle and to the U.S. public in June.

For example, the Synthesis Group's report stated, the DOE has explored nuclear power and propulsion, solar cells, fuel cells, advanced batteries, new materials, manufacturing, computing, the medical effects of radiation, and the processing of natural resources "from dirt into finished products," Nozette said. Similarly, the DOD has dealt with automated systems requiring less in the way of real-time mission control.

How the multiagency national space effort would work on a day-to-day basis has yet to be defined. The Synthesis Group's report recommended that a National Program Office be established by Executive Order, to "clearly enumerate staffing, budgeting and reporting relationships and responsibilities" of NASA, the DOD, and the DOE.

For its part, the DOE sees itself "in a supporting role, not a true operational role like NASA or the DOD," said the DOE's Carey. "If energy is to be used off the earth, we [the DOE] should be involved, but we're not here to build an empire."

APOLLO NO GUIDE. On the face of it, Bush's clarion call for the Space Exploration Initiative echoes that of President John F. Kennedy, who on May 25, 1961, committed the United States to "achieving the goal before this decade is out of landing a man on the Moon and returning him safely to the Earth."

But the United States has not been galvanized to another Apollo-scale space race. On the contrary, the reaction has been "tepid," according to U.S. Congressman Bill Green, a New York Democrat and ranking minority member of the House Appropriations subcommittee that voted in May to kill funds for the space station Freedom.

(Continued on p. 45)

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SPECTRUM

SPECIAL GUIDE TO

DATA COMMUNICATIONS

HIGH-SPEED NETWORKS AND INTERCONNECTION

FIBER-BASED LANS • BROADBAND ISDN • TAXONOMY OF A LAN • AND MUCH MORE

DATA COMMUNICATIONS

SPECIAL GUIDE

COVERING: *High-speed local-area networks (LANs)*
Interconnection of LANs
Wide-area networks (WANs)
Broadband-ISDN networks
Gigabit-per-second testbeds

PLUS: *Defining terms*
To probe further
Editorial index

A surge in data communications system capabilities is finding vent in a flood of new products and services. Not only is this bonanza expected to benefit electrical and electronics engineers in their capacity as users, but it is also generating new opportunities for them in the way of markets and jobs. The signs are that the worldwide markets for text, data, and image communications—all employing new forms of packet-switching technology—will increase dramatically in the next few years, predicts Insight Research Corp., Parsippany, N.J., a market research firm specializing in the telecommunications industry. More specifically, text and data communications will grow from US $36 billion in 1990 to $94 billion in 1994; image, from $22 billion to $74 billion over the same period, according to the firm.

That data communications needs are growing is evident from the demands of design engineers. Imagine this scenario: a group of 10 engineers at work on a 20 000-transistor application-specific integrated circuit (ASIC) would like to share, in real time, the circuit design and simulation files with 10 other colleagues in disparate locations. The transmission capacity needed for this task will become affordable as efforts in the design, standardization, and specification of gigabit-per-second networks progress.

Meanwhile, high-speed local-area networks (LANs) in the 50–150-megabit-per-second range are becoming available; they comply with the fiber-distributed data interface (FDDI) and distributed queue dual bus (DQDB) standards ["High-speed local-area networks," p. 26].

As LANs proliferate, the need for interconnecting them into such larger entities as metropolitan-area networks and the even larger wide-area networks (MANs and WANs) becomes apparent. Here there are a number of tradeoffs, and the options for interconnecting LANs run from bridges to routers and gateways ["Interconnecting LANs," p. 32].

What about multimedia transmission—video, text, and graphics? It will soon be upon us. Specifications for this capability are being developed by the International Telegraph and Telephone Consultative Committee (CCITT) in its recommendations for broadband integrated-services digital network (B-ISDN). Simultaneously the CCITT is refining its recommendations for synchronous digital hierarchy (SDH), which is expected to become part of the B-ISDN infrastructure and has evolved from Bell Communications Research Corp.'s synchronous optical network, or Sonet, concept ["B-ISDN and how it works," p. 39].

Representative high-speed LANs and systems for interconnecting LANs are tabulated, as well as prototype and developmental B-ISDN switches and Sonet-compatible integrated circuits. The tables were developed by *IEEE Spectrum* staff in consultation with the authors and an advisory board of experts in the fields addressed in the report.

Because the subject of data communications is highly specialized, many readers would do well to acquaint themselves with the main terms ["Defining terms," p. 24] before reading the feature articles.

References for further reading and research are cited ["To probe further," p. 43], and, last, but not least, an editorial index for table entries, as well as an advertisers index, may help those making inquiries about the products [Index, p. 44].

Gadi Kaplan Senior Technical Editor

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OPNET
Modeling Manual

Defining terms

Access line: the portion of a leased line that permanently connects the user with the serving central office or wire center.
Accunet: data-oriented digital services from AT&T Co.
ACK: control code or designation for a positive acknowledgment of a received transmission.
Alternate routing: a transmission completed over a circuit route other than the preferred but unavailable route.
API: application program interface, software that can be referenced by an application program to access underlying network services.
Application layer: a logical entity of the OSI model; the topmost of the structure's seven layers and the one that interfaces to the network user.
Ardis: advanced radio data information service, a wireless network service of Motorola Inc. and IBM Corp.
ANSI: American National Standards Institute.
ASCII: American National Standard Code for Information Interchange.
Asynchronous: in data communications, transmission that is not related to a specific frequency or timing; also, start/stop transmission, characterized by bytes encapsulated with start and stop bits.
ATM: asynchronous transfer mode; a type of packet switching that transmits fixed-length units of data. It is asynchronous in that the recurrence of cells does not depend on the bit rate of the transmission system—only on the source requirements.
ATM cell delineation: a means of determining the cell's boundaries in a continuous flow of bits.
ATM cross-connect: a switch that employs only one of two control fields to identify cells belonging to a channel; it uses the virtual path identifier, not the virtual channel identifier.
Backbone: a network designed to interconnect lower-speed channels.
BellCore: Bell Communications Research; established by the AT&T divestiture, it represents and is funded by the regional Bell holding companies.
B-ISDN: broadband integrated-services digital network.
Bridge: a device that interconnects LANs using the bottom two OSI layers.
Broadband: supporting a wide range of frequencies.
Bus: a local-area network topology where all interconnected computers are aware of all transmissions, but each computer receives only those transmissions addressed to it.
CBDS: connectionless broadband data service, the definition of which is emerging from the European Telecommunications Standards Institute; expected to be equivalent to and compatible with SMDS.
CCITT: International Telegraph and Telephone Consultative Committee.
Cell: a fixed-length unit of data.
Cell relay: a packet transmission technology based on IEEE 802.6 for MANs and on ATM for WANs.
Circuit switching: a way to establish a transmission path between two points whereby a fixed capacity is dedicated to a call until the call is completed.
CLS: connectionless server.
CMIP: common management information protocol, an ISO network management protocol.
Connectionless convergence protocol: a set of rules emerging from the CCITT that govern one aspect of ATM transmission; likely to correspond to a portion of SMDS.
Connectionless mode transfer: in a packet-switched network, the individual transfer of each data packet, independent of those that precede or follow it; the notion of an end-to-end connection does not exist.
Connection-oriented: said of a packet-switched network through which a path is established and maintained for the duration of a call, even though physical resources of the path are still packet switched among many users.
CSMA/CD: carrier-sense multiple access with collision detection, a LAN access method.
Datagram: a finite-length packet with sufficient information to be routed from source to destination independently of previous transmissions.
DDP: distributed data processing, a network of geographically dispersed, logically interconnected processors that share common resources.
DDS: Dataphone Digital Service, a carrier offering that uses 2.4–56 kb/s.
DECnet: Digital Equipment Corp.'s proprietary network architecture.
DIS: draft international standard, an ISO standards document that has been registered and numbered but not yet given final approval.
DQDB: distributed queue dual bus, the best-known implementation of a reservation-strategy MAN, in which each station on a 150-Mb/s twin bus records and maintains reservations in a local queue.
EMA: Enterprise Management Architecture, a DEC architecture.
EMS: element management system, part of AT&T's UNMA.
ETSI: the European Telecommunications Standards Institute.
FCFS: first come, first served, descriptive of the order of packet transmissions—as contrasted with round robin—in multiple access to linear-bus LANs, where stations may place reservations in a separate logical channel.
FDDI: fiber-distributed data interface, ANSI's architecture for a MAN; a network based on the use of optical-fiber cable to transmit data at 100 Mb/s.
FDDI-II: a variant of FDDI that supports isochronous traffic.
Flow control: the ability of some network nodes to manage different data rates by means of buffering schemes or by reducing the data flow from a sending station.
Frame relay: an upgrade of X.25 packet switching.
FT1: fractional T1, a common-carrier transmission offering in multiples of 64 kb/s.
FTAM: file transfer, access, and management, an ISO protocol.
Gateway: a device that interconnects dissimilar LANs that employ different high-level protocols.
HDLC: high-level data link control, a CCITT-specified bit-oriented protocol.
HIPPI: high-performance parallel interface, a proposed gigabit-per-second interface to supercomputer networks (formerly known as high-speed channel), under evaluation by an American National Standards committee (ANSI X3T9.3). HiPPI is based on the use of parallel copper wires as connections.
INMS: integrated network management system, part of AT&T's UNMA.
Internet: a network that interconnects two or more other networks.
IPX: internetwork packet exchange, Novell Inc.'s operating system.
ISDN: integrated-services digital network, a CCITT-defined digital network.
ISO: International Organization for Standardization.
Isochronous: equally timed; in data communications, timing information is transmitted on the channel along with data—sending asynchronous data by synchronous means; the method involves synchronously sending the asynchronous characters between each pair of start and stop bits.
LAN: local-area network, typically a high-speed network (usually in the megabit-per-second range) wherein all segments of the transmission are situated in an office, building, or campus environment; ownership is by the user organization.
LAPB: link access procedure-balanced, descriptive of a CCITT-specified data link level protocol.
LATA: local access and transport area, a local telephone company serving area.
LLC: logical link control, the IEEE 802-defined third layer of its LAN reference model.
MAN: metropolitan-area network, a "stretched" LAN providing data communications over a distance of about 50 km, generally associated with the IEEE 802.6 MAN standard.
MSN: Manhattan street network, a mesh architecture using wavelength-division multiplexing.
Network architecture: the conceptual description of the way communication is accomplished between data-processing gear at disparate sites; it also specifies the processors and terminals, protocols, and software that must be used.
N-ISDN: narrowband integrated-services digital network.
Node: termination point for two or more communications links.
OCC: other common carrier, a carrier other than AT&T Co. and its former affiliates.
Optical fiber: any filament or fiber made of dielectric materials and consisting of a core (to carry, for example, laser-generated light signals) and a surrounding cladding, which reflects the signal back into the core. Thin threads of glass are most commonly used, but plastic fiber is sometimes chosen for its flexibility.
OSI: open systems interconnection; ISO's reference model for enabling multivendor systems to intercommunicate.
OSPF: open shortest path first, a newly proposed routing standard.
Packet: a unit of data, consisting of binary digits including data and call-control signals, that is switched and transmitted as a composite whole.
Packet switching: a data-transmission technique whereby physical resources on a path are switched on a per-packet basis, using control information in the header of each packet; it can operate in either connection-oriented or connectionless mode.
Passive optical network: an emerging technique in the public network for multiplexing many individual local loops on a single optical fiber cable.

Payload type: indicator in the header of an ATM cell that makes it possible to identify the type of information conveyed in the payload of a cell.

PBX: private branch exchange, a circuit-establishing telecommunications switch.

PDU: protocol data unit, an ISO term referring to a packet of information exchanged between two network-layer entities.

PCN: personal communication network, an envisioned combination of MANs and wireless networks.

Plesiochronous: in multiplexing, a method used when not all the data flows have the same bit rates and are adjusted by inserting or deleting bits.

Private network: one established and operated by a private organization or corporation.

Protocol: a set of procedures required to establish, maintain, and control communications; it can exist on many levels within a network.

Public network: a network operated by a common carrier or telecommunications authority to provide transmission services to the public.

RBHCs: regional Bell holding companies, AT&T's former affiliates.

Ring: in local-area networks, a configuration of computing devices whereby all are interconnected in a ring topology; communications between any two points must include the intermediate points.

RIP: routing information protocol, a router algorithm.

Router: in local-area networks, a device that employs the bottom three OSI layers to interconnect dissimilar networks.

SDH: synchronous digital hierarchy; in SDH networks multiplexing is done on a synchronous basis. See also Sonet.

Server: a processor that supplies a network with a specified service, such as a routing function.

Single-mode optical fiber: a fiber designed to propagate light of only a single wavelength.

SMDS: switched multimegabit data service, a BellCore-developed standard for the public carriers.

SNA: systems network architecture, IBM's reference model.

SNMP: simple network management protocol; used to manage and monitor networks based on TCP/IP.

Sonet: synchronous optical network; describes a set of common characteristics for optical transmission of digital signals; a BellCore-proposed protocol for fiber networks.

SRP: source routing protocol, an IBM routing specification.

Star: in local-area networks, a configuration of computing devices in which each user is connected by communication links radiating out of a central hub that handles all communications.

Station: an input or output point of a communications system.

STP: spanning tree protocol, an IEEE 802.1 routing specification.

Synchronous: having a constant time interval between successive bits or characters; using no redundant information, such as start and stop bits, to identify the beginning and the ending of the unit of data—to be contrasted with asynchronous.

T1: 1.544 Mb/s.

T3: 44.736 Mb/s (commonly called 45 Mb/s).

TCP/IP: transmission control protocol/internet protocol, an internetworking standard originated by the U.S. Department of Defense.

Topology: the logical and/or physical arrangement (in, say, a star or ring) of stations on a network.

Unix: an AT&T-originated operating system.

UNMA: unified network management architecture, AT&T's network management scheme.

WAN: wide-area network, a network that links data-processing and telecommunications equipment over a larger geographic area than a single work site or a metropolitan area: it typically links cities and is usually based on X.25 packet switching. It may be implemented by a private corporation or by a public telecommunications operator.

Wavelength-division multiplexing (WDM): an optical-fiber transmission technique that uses different light wavelengths to send data; the technology of choice for ultragigabit LANs (data rates into the terabit-per-second range).

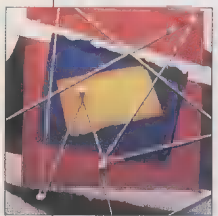
X series: a group of CCITT recommendations that pertain to data networks.

X.25: CCITT recommendation that specifies how user data terminal equipment should interface with data circuit-terminating equipment for packet-switched networks.

X.25 packet switching: networking that uses the CCITT protocol recommendation X.25.

High-speed local-area networks

Fiber-distributed data interface (FDDI) and distributed queue dual bus (DQDB) are typical for the 50–150-Mb/s range



The push of advancing technology and the pull of new, more-demanding user applications are stimulating the development of local-area networks (LANs) that operate at speeds much higher than those of just a few years ago. High-speed LANs in the 100-megabit-per-second range are now commercially available, and prototypes operating at speeds of 1 gigabit per second are being tested.

Though LANs may be classified according to their topology, access protocol, and transmission medium, for present purposes the data rate is the most appropriate criterion. Along these lines, the four main classes of LANs are:

- Low- and medium-speed LANs—with data rates up to 10–20 Mb/s. This class includes the vast majority of conventional LANs such as copper-wire-based Ethernet and token ring, as well as the more recently introduced wireless LANs.
- High-speed LANs—with data rates ranging from 50 to 150 Mb/s. Typical entries are the fiber-distributed data interface (FDDI) and the distributed queue dual bus (DQDB). The most common medium is optical fiber.
- Supercomputer LANs—with data rates of about 800 Mb/s. Typical entries are UltraNet and CP* (CP stands for crossbar processor). Because of the limited geographical range of these networks, copper cable (32 or 64 parallel connections) is the most common transmission medium.
- Ultragigabit LANs—with data rates into the terabit-per-second range. Although no commercial offerings yet exist, several experimental prototypes are being developed (one is AT&T Co.'s multihop network). The medium is the single-mode fiber. The technology of choice is wavelength-division multiplexing (WDM).

Worth a look, even in a high-speed context, are the recently introduced low- and medium-speed wireless LANs. Their biggest plus is that they need no recabling every time the network is reconfigured. But they offer other advantages as well—the ease of moving workstations (some of which may even be portable) and the ready ability to connect to a metropolitan personal communications network. Although wireless LANs do not operate at high speeds, they may be interconnected via high-speed backbone networks.

Two different techniques can be used for wireless short-range voice and data communications: radio and infrared. Radio tends to yield higher data rates, but incurs higher costs and is more susceptible to interference. Infrared is more limited in bandwidth (because of multipath dispersion) and in coverage (because of line-of-sight obstructions). It is, however, a less expensive technology; furthermore, infrared does not require licensing, as does radio in many cases.

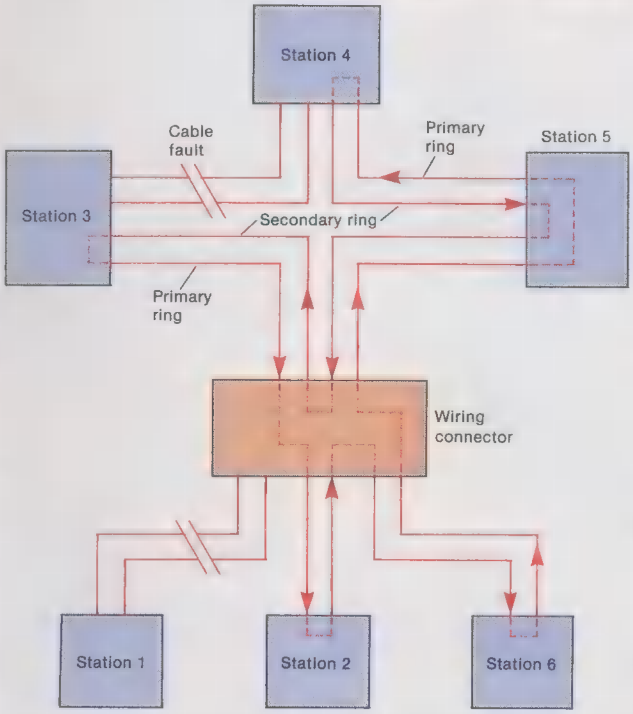
The greatest promise of a wireless LAN is its potential for connecting with future wide-area wireless networks. In fact, besides voice cellular radio networks, several wireless networks are now emerging to offer data services over wide geographical areas, such as Motorola Inc.'s and IBM Corp.'s Ardis (for advanced radio data information service).

HIGH-SPEED LANs. The metropolitan-area network (MAN) emerged in the mid-1980s when the proliferation of LANs led to the need for new networks that could interconnect others and carry aggregate traffic several orders of magnitude higher than that of an individual LAN. For such networks, it was necessary to employ interconnection speeds of 100 Mb/s, geographical-area coverage of up to 10 km, and network capabilities that would support hundreds of stations.

The physical means to this end was optical fiber. Advances in lightwave technology—specifically, fiber optics—enabled the fabrication of relatively low-cost, low-attenuation fibers and high-quality optical transmitters, detectors, and passive components. All this enabled a high-speed backbone network to link LANs across metropolitan regions, creating a new version of "stretched" LAN, or the MAN, which has many characteristics in common with the LAN.

The applications and services that emerged for the MAN architecture covered voice, video, and imaging areas. For example, in a campus environment, video lectures were distributed and videoconferencing was supported; in a hospital, the radiologist was able to retrieve X-rays from an image database.

MULTITOKEN PROTOCOL. One kind of MAN starts from first-generation LAN architectures (specifically, the IEEE standard 802.5 token ring), replaces the copper-based cable with single-mode or multimode fiber, and then implements FDDI, a 100-Mb/s dual ring. FDDI's multitoken protocol enables several stations at a time to maintain outstanding frames on the ring and permits operation up



[1] A dual, counter-rotating ring topology for connecting stations achieves fault tolerance to link failures in the network. Using multiple tokens removes the potential inefficiencies of the single-token protocol that is specified in IEEE 802.5.

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Joseph A. Bannister Aerospace Corp.

to 200 km in distance [Fig. 1].

A variant of FDDI, called FDDI-II, supports isochronous—or equally timed—traffic. Isochronous transmission is a method for sending both synchronous and asynchronous data by synchronous means; it involves multiplexing the synchronous and asynchronous data in synchronous frames.

In FDDI and FDDI-II, each frame is removed by the originating station after a full rotation around the ring. Efficiency can be improved (by as much as four times, on average) if the destination removes the frame. A recently proposed buffer-insertion ring, the Meta Ring, does in fact offer such destination removal, thus upgrading the FDDI speed to 800 Mb/s.

LINEAR BUSES. Since the pioneering Ethernet and token bus protocols do not scale up to high speeds, a new access protocol, called implicit token (or ordered access), has been introduced.

The implicit token basically is a burst of carrier issued by a designated end station. As backlogged stations append their frames in sequence after the token, a "train" is formed. Once a cycle is completed, the end station starts the next cycle. No token processing is required. Attenuation problems can be corrected by regenerating and amplifying the signal at each interface.

Several implicit-token fiber-bus architectures were proposed and researched in the 1980s, including ExpressNet, U-Net, FasNet, MetroCore, Magnet, and LION. One proposed improvement to implicit token is Buzznet, a hybrid protocol featuring random-access mode under light load and token mode with a heavy load.

An alternative approach to multiple access to a linear bus is reservation. For this form of access, stations place reservations in a separate logical channel. The order of packet transmissions is first come, first served, as opposed to the round robin order in token schemes.

TWIN BUS. The best-known implementation of a reservation strategy is DQDB, a 150-Mb/s twin bus in which each station records and maintains the reservations in a local queue [Fig. 2].

The strong points of DQDB are simplicity and extreme efficiency of the distributed reservation mechanism. Reservations are piggybacked onto data packets, thus avoiding cycle latency and providing channel efficiency close to unity when operating with a single sending station. The strategy has won rapid and broad acceptance and been chosen as the MAN standard by the IEEE 802.6 Committee.

SUPERCOMPUTER LANs. Proposed as a high-speed interface for supercomputer networks is HiPPI (high-performance parallel interface), which is based on the use of parallel copper wires. HiPPI is now being evaluated by an American National Standards Institute committee (ANSI X3T9.3).

If supercomputers share a network—the proposed supercomputer LAN—they can reduce the communications costs and increase the flexibility of interconnecting high-definition graphics workstations and supercomputers for scientific visualization applications. They could be used, for example, in the imaging of physical phenomena, such as the dynamic fluid turbulence of a jet engine. Other proposed applications are memory-to-memory transfer and load sharing among the supercomputers.

LAN LIMITS TODAY. To get back to lightwave LANs, the current types use simple point-to-point topologies that limit the designer's flexibility and make the implementation of multichannel networks problematic. But with effective use of optical couplers and broadband optical amplifiers, LANs and MANs can be designed with non-point-to-point topologies, such as trees and stars.

A tree topology, for instance, can distribute optical signals to more than 1000 stations over a wide geographical area, using only passive optical couplers and optical amplification at the root of the tree. The commercialization of a broadband optical amplifier would be necessary, however, before tree-like multichannel networks become a reality.

Today's high-speed LANs such as FDDI and DQDB already employ transmission over multimode optical fibers based on direct detection and light-emitting diodes (LEDs). Using LEDs to transmit over single-mode optical fibers, networks can reach speeds in the 1-Gb/s range. Research proposals for future LANs and MANs are often premised on the emergence of wavelength-division multiplexing (WDM) as a means of funneling gigabit-per-second transmissions onto terabit-per-second fiber networks.

More advanced research proposals might even combine WDM with all-optical transmission, where optical signals are switched by purely photonic means. This method eliminates undesirable and time-consuming electro-optical conversions within the network.

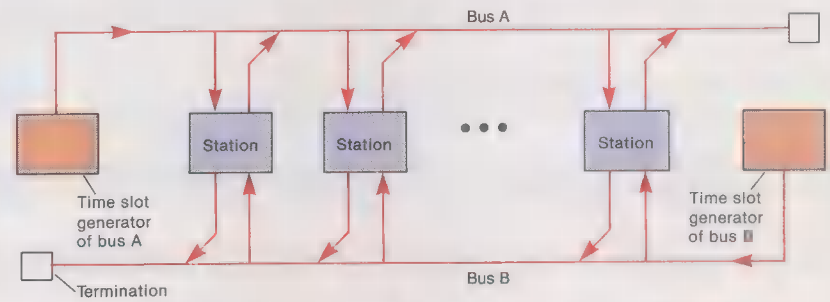
All-optical networks could be constructed as an arbitrary mesh using linear combiners/dividers or wavelength-selective switches. Though not currently available, these optical devices are undergoing extensive laboratory experimentation.

To date, the best-known mesh architecture is the Manhattan street network (MSN), which is organized as a square grid. To avoid store-and-forward buffering, the relatively simple routing scheme called deflection routing is implemented at the nodes (or, the grid crosspoints). In a grid, each node is assigned exactly two inputs and two outputs.

If both inputs are competing for the same output, one packet is sent to the correct output; the other, to the "wrong" output, and then forced to take an around-the-block detour. This feature, albeit somewhat wasteful in throughput, avoids nodal buffering, thus reducing station costs.

In MSN's favor are the good metropolitan coverage, the simplicity of the protocols and nodal implementations, and the potentially unlimited throughput offered by a topology with multiple concurrently available paths. The drawback of MSN, however, is the inefficiency of its broadcast and isochronous traffic support.

The WDM network architecture is an attempt to combine the path concurrency of the MSN and the broadcast and isochronous support features of more conventional MANs. But progress in lightwave transmission is not now feasible without further progress in digital electronics.



[2] Although called a bus, the distributed queue dual bus's (DQDB's) topology is physically a dual loop that permits the local-area network to recover when a segment (link) between nodes fails. To provide support for isochronous traffic, DQDB uses fixed-length packets that fit within a given time slot.

Today's high-speed data transmission relies on fast electronics that can provide serial data to a transmitter at network rates. And for the immediate future, hybrid (optical and electronic) networks and user devices will remain dependent on digital speeds.

But, since the bandwidth of a single-mode optical fiber is in the terabit-per-second range, clearly WDM will have to be used to allow a serial electronic interface to tap into this enormous bandwidth. To transmit at gigabit-per-second speeds, electronic transceivers must be clocked at gigahertz rates, which will apparently require the use of high-performance integrated circuitry such as GaAs or emitter-coupled logic (ECL).

ULTRAGIGABIT NETWORKS. Traffic projections for the mid-1990s envision an overall network capacity of hundreds of gigabits per second. The common solution to achieving

Representative high-speed local-area networks (LANs)[1]

Data rate, Mb/s	Encoding scheme	Transmission medium	Max. no. of stations	Max. route length, km	Topology/ redundancy[2]	Access protocol	Max frame size, bytes	Class of service[3]	Standards	Comments
[illegible] ([illegible]), [illegible] Communications Corp., US $7200–2500 (Ethernet 802.3), $15 000 (FDDI)[4]										
100 (FDDI); 10 (Ethernet 802.3)	Per std. (802.x-IEEE, ANSI X3T9.5-FDDI)	All media	500 on backbone (FDDI); 1024 per subnetwork (Ethernet)	2 per hop (FDDI) or per standard (Ethernet 802.3)	Ring (FDDI), bus (Ethernet)/ redundancy supported	CSMA/CD (Ethernet); token (FDDI)	1518 (Ethernet); 4500 (FDDI) per std.	All three modes	ANSI X3T9.5	Accommodates up to 32 mixed FDDI and Ethernet multiport bridges
Codenet 9540/9543 FDDI Adapter (1989), Codenoll Technology Corp., $4995/$7495										
100	4B/5B	Multimode fiber	1000	2 between nodes; 200 entire net	Ring/ring	Token	4500	Asynchronous	ANSI X3T9, SMT6.2	FDDI Type A or Type B adapter
DECconcentrator 500 (1990), Digital Equipment Corp., $1125 (low-power optics), $667 (wire)										
100	FDDI/4B/5B	Multi- or single-mode fiber; ThinWire and shielded pair	500 stations or 1000 connections	200	Ring of trees/ dual ring and dual homing	FDDI; timed token	4500	See footnote 6.	ANSI X3.139, X3.148, X3.166; FDDI	ANSI-compliant single- and multimode and low-power multimode options, plus shielded twisted-pair wire and ThinWire technology
RingMaster 7200 (1990), FiberCom Inc., $11 795										
100 multimode	4B/5B	Multi- or single-mode fiber	1000	200	Ring/counter-rotating rings	Token	4500	Asynchronous	X3T9; IEEE 802.1d, 3, 5	FDDI bridge for Ethernet and token ring
Magnum 100 (1990), [illegible] Corp., $4850 and up per node										
100	4B/5B	Multi- or single-mode fiber	[illegible] nodes per ring	45	Ring/dual counter-rotating rings	TDM	N.A.	Isochronous	Proprietary	Supports 16 different signals on a 100-Mb/s backbone[7]
FX8610 (1991), Fibronics International Inc., $625										
100	4B/5B	Multi- or single-mode fiber	48	N.A.	Ring/dual ring	Token	1500	Asynchronous	X3T9.5, 802.3	—
Fibertalk 3000 (1991), Integrated Networks Corp. (In-Net), $25 000										
100	4B/5B	Multimode fiber	500	100	Ring/dual ring	Token	4500	Asynchronous	ANSI X3T9.5	IBM or PCM channel extension with FDDI
V/FDDI 4211 Peregrine (1990), Interphase Corp., $10 995 per single unit										
100	4B/5B	Multimode fiber	500 dual-attached	100	Ring/dual ring	Token	4500	Synch or asynch	ANSI X3T9.5	6U VME; Multibus I; Unix and real-time drivers available
MR-23VX LAN (1989), Microwave Radio Corp., $6500 per terminal										
10	FM/FSK	Microwave	Unlimited	0.13	Ethernet or token ring/dual setup	Transparent	N.A.	All modes	IEEE 802.3, 802.5	Ethernet and token-ring products
Altair (1991), Motorola Inc., $[illegible]										
15	4-level FSK	Radio (18 GHz)	32 per microcell	N.A.	Star/36 paths	Random access	3750	Asynchronous	IEEE 802.3	High-speed wireless LAN

this speed is a multilayer architecture. This would include a backbone loop at the top of the hierarchy, and several layers of distribution loops. Access would be best achieved with WDM.

Neither FDDI nor DQDB architecture is well suited to exploit WDM. Because WDM permits multiple channels in a fiber, it can, in principle, expand the effective data rate of a single fiber from the gigabit- to the terabit-per-second range. But to implement WDM, an FDDI- or DQDB-network would require a splitter, a filter, and a combiner at each interface, plus a wideband amplifier to make up for power loss—a very expensive proposition.

Another weak point of the multilayer configuration is the bridge that connects the layers. Its practical throughput limit is probably about 100 kilopackets per second—and state-of-the art bridges today can forward, at most, 20 kilopackets per second. Furthermore, it would be difficult to satisfy the tight delay constraints of voice and video connections across several bridges.

Only an all-optical WDM network will suffice to achieve ultragigabit speeds—one totally ''transparent'' to WDM, free of any processing components. This has led to the development of a new generation of LANs and MANs, based on passive optical components and WDM techniques. The key components of a WDM optical network are:

- Passive optical elements, including couplers, splitters, and combiners.
- Wavelength-division-multiplexing gear, namely tunable lasers, detectors, filters, and wavelength switches.
- Network management, to control wavelength allocation and dynamically reconfigure the topologies according to traffic patterns and user demands.

'MASS OF GLASS.' The most commonly reported WDM architecture consists of a passive optical broadcast medium (star, tree, or bus)—the so-called mass of glass—on which several wavelengths can be multiplexed. Since the multiplexing and switching is done at the periphery of the mass of glass, the primary challenge is how to apply channel-access control.

Some approaches propose mesh-type topologies combined with wavelength-sensitive optical switches; light paths can then be established in the same manner as connections in a conventional circuit-switched network. But the two main approaches that have been proposed do something different. The first leaves it to the transmitter and receiver to pick a time and wavelength that is appropriate for sending each packet. The second allots a few frequencies to each station and transmits the packets through the intervening nodes.

The transmitter/receiver-based approach employs time-frequency division to define a network-wide, time-slotted reference frame. A source and destination pair must reserve a time slot in the frame for the transmission of each packet and must agree on the frequency (wavelength) each will use. This system can be quite efficient, but it involves not only extra overhead that is necessary to achieve source and destination coordination but also the additional cost (and

Representative high-speed local-area networks (LANs)[1] (continued)

Data rate, Mb/s	Encoding scheme[2]	Transmission medium	Max. no. of stations	Max. cable length, km	Topology/redundancy[3]	Access protocol	Max frame size, bytes	Class of service[4]	Standards	Comments
[illegible] Network [illegible], $6250 [illegible]										
800 and 1600	HP 21/24 (end '91, for fiber)	Twisted-pair, single-mode fiber, coax '91	64 (HiPPI)	25/100 m (HiPPI/coax), 10 km (fiber)	Crosspoint switch/double channel	HiPPI-FP	Virtually unlimited	All modes	ANSI X3T9.3	HiPPI products
ODS 1090 [illegible]										
100	4B/5B	Multi- or single-mode fiber	42	34	Ring or star/dual ring	Token	4500	N.A.	ANSI X3T9	FDDI products
FDDI Ring 200 [illegible]										
100	4B/5B	Multi- or single-mode fiber	8000	200	Ring or star/ring	Token	4500	Asynchronous	SNMP; 802.5; FDDI	FDDI and token-ring products
VCOM-100 [illegible], SBE [illegible]										
100	4B/5B	Multimode fiber	1000	200	Ring/ring	Token	4500	Synchronous	ANSI X3T9.5	FDDI communications controller[6] for VMEbus systems
FDDI XPress [illegible], Silicon [illegible] 000										
100	4B/5B	Multimode fiber	500	200	Ring/dual ring	Token	4500	Asynchronous	X3T9.5; SMT6.2	—
SUMINET 3500 [illegible]										
100	4B/5B	Single- or multi-mode fiber	1000	—	Ring/dual counter-rotating ring	Token	4500	Asynchronous	X3T9.5; SMT6.2	FDDI products
FDDI/DX [illegible], Sun [illegible] 500										
100	4B/5B	Multimode fiber	500	—	Ring/dual ring	Token	4500	Synchronous	ANSI	—
[illegible], [illegible] $1780										
100	4B/5B	Multimode fiber	255 per LAN	6.1 (1 km bet. nodes)	Star, distributed/not supplied	Token	512	Asynchronous	Arcnet —none	—
ASM [illegible] FDDI Bridge [illegible] Inc., $15 000										
100	X3T9.5-	Multimode fiber, co-	16 000	2	Ring/dual	Token	1500	Syn-	ANSI [illegible]T9.5	FDDI bridge to Ethernet

Standards Institute.
multiple access with collision detection.
ata interface.
lulation/frequency-shift keying.
parallel interface.
HiPPI framing protocol.
SI standard for a HiPPI integrated circuit set.

it software.
nanagement protocol.
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A). He was previously net-
manager for Network Anal-
eat Neck, N.Y., where he led
ter network design projects
nment and industry. He also
n Telecommunications, Ma-
Calif., where he participated
ment of an integrated packet
work. He holds the graduate
neering from the Politecnico
M.S. and Ph.D. degrees from

nnister (M) is an engineer in
architecture and verification
the Aerospace Corp., El
. He has held positions in re-
velopment at Sytek, Unisys,
has conducted research and
high-speed networking, net-

FUTURE ISSUES AND TRENDS. The interconnection of ultragigabit networks with high- and medium-speed LANs is still an open research area. As the planning and standardization of wide-area broadband integrated-services digital networks (B-ISDNs) pro-

is the standard transport protocol of networks that conform to the CCITT's current recommendations for B-ISDN.

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work design, network management, performance evaluation, and dependable computing. He earned a B.S. in mathematics from the University of Virginia and an M.S. in engineering plus M.S. and Ph.D. degrees in computer science from UCLA.

Representative high-speed local-area networks (LANs)[1]

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Galactica [illegible] 000 [illegible]										
100 (FDDI); 10 (Ethernet 802.3)	Per std. (802.x-IEEE, ANSI X3T9.5-FDDI)	All media	500 on backbone (FDDI); 1024 per subnetwork (Ethernet)	2 per hop (FDDI) or per standard (Ethernet 802.3)	Ring (FDDI), bus (Ethernet)/ redundancy supported	CSMA/CD (Ethernet); token (FDDI)	1518 (Ethernet); 4500 (FDDI) per std.	All three modes	ANSI X3T9.5	Accommodates up to 32 mixed FDDI and Ethernet multiport bridges
Codenet 9540/9543 FDDI [illegible]										
100	4B/5B	Multimode fiber	1000	2 between nodes; 200 entire net	Ring/ring	Token	4500	Asynchronous	ANSI X3T9, SMT6.2	FDDI Type A or Type B adapter
DECconcentrator 500 [illegible]										
100	FDDI/4B/5B	Multi- or single-mode fiber; ThinWire and shielded pair	500 stations or 1000 connections	200	Ring of trees/ dual ring and dual homing	FDDI; timed token	4500	See footnote 6.	ANSI X3.139, X3.148, X3.166; FDDI	ANSI-compliant single- and multimode and low-power multimode options, plus shielded twisted-pair wire and ThinWire technology
RingMaster [illegible]										
100 multimode	4B/5B	Multi- or single-mode fiber	1000	200	Ring/counter-rotating rings	Token	4500	Asynchronous	X3T9; IEEE 802.1d, 3, 5	FDDI bridge for Ethernet and token ring
[illegible] 100 [illegible], Fibermux [illegible] $4850 [illegible]										
100	4B/5B	Multi- or single-mode fiber	8 nodes per ring	45	Ring/dual counter-rotating rings	TDM	N.A.	Isochronous	Proprietary	Supports 16 different signals on a 100-Mb/s backbone[7]
[illegible] $625										
100	4B/5B	Multi- or single-mode fiber	48	N.A.	Ring/dual ring	Token	1500	Asynchronous	X3T9.5, 802.3	—
[illegible] 3000 [illegible] 000										
100	4B/5B	Multimode fiber	500	100	Ring/dual ring	Token	4500	Asyn-	ANSI	IBM or PCM channel exten-
V/FDDI [illegible]										
100	4B/5B	Multimode fi								
MR-23VX LAN [illegible] Radi										
10	FM/FSK	Microwave								
Altair [illegible] Motorola [illegible] $300										
15	4-level FSK	Radio (18 GH								

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reserve a time slot in the frame for the transmission of each packet and must agree on the frequency (wavelength) each will use. This system can be quite efficient, but it involves not only extra overhead that is necessary to achieve source and destination coordination but also the additional cost (and

Representative high-speed local-area networks (LANs)[1] (continued)

Data rate, Mb/s	Encoding scheme[2]	Transmission medium	Max. no. of stations	Max. cable length, km	Topology/ redundancy[3]	Access protocol	Max. frame size, bytes	Class of service[5]	Standards	Comments
[illegible]-152 (1991), Network Systems Corp., $5250 (HiPPI), $21 250 (fiber)										
800 and 1600	HP 21/24 (end '91, for fiber)	Twisted-pair, single-mode fiber, coax '91	64 (HiPPI)	25/100 m (HiPPI/ coax), 10 km (fiber)	Crosspoint switch/double channel	HiPPI-FP	Virtually unlimited	All modes	ANSI X3T9.3	HiPPI products
ODS 1090 (1991), Optical Data Systems Inc., $1330										
100	4B/5B	Multi- or single-mode fiber	42	34	Ring or star/dual ring	Token	4500	N.A.	ANSI X3T9	FDDI products
FDDI Ring 200 (1991), Raycom Systems Inc., $6000										
100	4B/5B	Multi- or single-mode fiber	8000	200	Ring or star/ring	Token	4500	Asyn-chronous	SNMP; 802.5; FDDI	FDDI and token-ring products
VCOM-100 (1991), SBE Inc., $4500										
100	4B/5B	Multimode fiber	1000	200	Ring/ring	Token	4500	Syn-chronous	ANSI X3T9.5	FDDI communications con-troller[8] for VMEbus systems
FDDI XPress (1991), Silicon Graphics Computer Systems Inc., $11 000										
100	4B/5B	Multimode fiber	500	200	Ring/dual ring	Token	4500	Asyn-chronous	X3T9.5; SMT6.2	—
SUMINET 3500 (series) (1989), Sumitomo Electric U.S.A. Inc., $9000 single attach basis										
100	4B/5B	Single- or multi-mode fiber	1000	—	Ring/dual coun-ter-rotating ring	Token	4500	Asyn-chronous	X3T9.5; SMT6.2	FDDI products
FDDI/BX (1989), Sun Microsystems Inc., $12 500										
100	4B/5B	Multimode fiber	500	—	Ring/dual ring	Token	4500	Syn-chronous	ANSI	—
TC3045 (1990), Thomas-Conrad Corp., $1790										
100	4B/5B	Multimode fiber	255 per LAN	6.1 (1 km bet. nodes)	Star, distribut-ed/not supplied	Token	512	Asyn-chronous	Arcnet —none	—
ASM 5360 FDDI Bridge (1990), Ungermann-Bass Inc., $15 000										
100 (FDDI); 10 (Ethernet)	X3T9.5-FDDI/ Ethernet 802.3	Multimode fiber, co-axial cable, un-shielded twisted pair	16 000 entries	2	Ring/dual counter-rotating rings	Token	1500	Syn-chronous or asyn-chronous	ANSI X3T9.5	FDDI bridge to Ethernet

1. Year first available and total network-connection cost amortized per connected station, whose complexity can raise the cost.
2. Refers to the encoding of the transmission. For example, 4B/5B (and all schemes with a 4 and a 5, or X3T9.5) means 4 bits (= 1/2 byte) encoded in a field of 5 bits. The 4B/5B scheme guarantees no more than three consecutive 0s; otherwise, a retransmission will be required.
3. Refers to a topology that includes a backup (dual) bus or ring, maintained as a "hot" standby; in a dual ring, packets rotate in opposite directions in the two rings.
4. Lower prices for Ethernet port or bridge; top price for FDDI bridge interface.
5. Refers to the three transmission modes: synchronous, asynchronous, and isochronous.
6. Accepts restricted or unrestricted synchronous or asynchronous; transmits unrestricted asynchronous.
7. Signals supported include Ethernet; token ring; IBM 3270, 5080, AS/400; T1; Wang; RS-232; RS-449, and LocalTalk.
8. Controller includes 25-MHz 68030 1M- or 4M-bit dynamic RAM, SMT software, and 6U-size single-attach station.

Key ANSI: American National Standards Institute.
CSMA/CD: carrier-sense multiple access with collision detection.
FDDI: fiber-distributed data interface.
FM/FSK: frequency modulation/frequency-shift keying.
HiPPI: high-performance parallel interface.
HiPPI-FP: proposed ANSI HiPPI framing protocol.
HP 21/24: proposed ANSI standard for a HiPPI integrated circuit set.
N.A.: not available.
SMT: station management software.
SNMP: simple network management protocol.
STP: spanning-tree protocol.
TDM: time-division multiplexing.

technology risk) of quickly retunable transmitters and receivers.

The second approach assigns maybe four fixed wavelengths to each user station (say, two for transmission and two for reception). Transmissions between any source and destination pair are accomplished by a multihop (store-and-forward) operation through the user stations. The store-and-forward processing requires additional peripheral electro-optical components.

The multihop solution offers lower transmitter and receiver costs at each station and lower control overhead, but its broadcast and real-time traffic-support techniques are inefficient. In view of these limitations, hybrid solutions that would combine the benefits of the two approaches are now under investigation.

FUTURE ISSUES AND TRENDS. The interconnection of ultragigabit networks with high- and medium-speed LANs is still an open research area. As the planning and standardization of wide-area broadband integrated-services digital networks (B-ISDNs) progress in study groups of the International Telegraph and Telephone Consultative Committee (CCITT) [see "B-ISDN and how it works," p. 39], the need emerges to find a way to interconnect high-speed LANs with the future gigabit-per-second wide-area networks.

One challenge for network designers and engineers who aim to interconnect LANs is always speed mismatch, which may lead to congestion at the inter-LAN gateways. Another is the design of gateways capable of switching hundreds of megabits per second.

But the B-ISDN-to-LAN interconnection presents an entirely new challenge: the interfacing of the "connectionless" environment, which is typical of LANs, with the connection-oriented environment of the asynchronous transfer mode (ATM), which is the standard transport protocol of networks that conform to the CCITT's current recommendations for B-ISDN.

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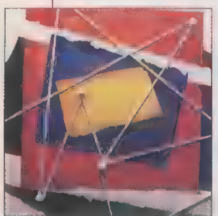
Interconnecting LANs

Bridges, routers, and gateways tie together LANs spread over areas from a single building to a metropolitan area



Local-area networks (LANs) can be linked within a highrise or across a campus, a city, or even a country. One means of interconnection is the 100-Mb/s fiber-distributed data interface (FDDI) specified by the American National Standards Institute (ANSI); it is an ideal high-bandwidth backbone for interconnecting the LANs within a multistory building or housed in several buildings in a campus-like environment. For buildings or campuses that require less bandwidth, planners may use an Ethernet or token ring LAN as the backbone. And truly far-flung LANs can be interconnected either by leased lines at various speeds (typically from 19.2 kb/s to 1.544 Mb/s) in a point-to-point or mesh topology or else by packet-switched subnetworks.

Many products are now available for integrating an enterprise's LANs. The T1 multiplexer is the simplest; then, in order of complexity, come bridges, routers, and gateways. By the time that numerous LANs are latching onto a backbone network, a whole new set of considerations comes into play—from network planning, transmission facilities, and switched services to security and network management.

T1 MULTIPLEXERS. Even T1 (1.544-Mb/s) multiplexers, by employing speed-adaptation devices, can interconnect LANs into a wide-area network (WAN), provided all the LANs use layer 1 of the open systems interconnection (OSI) reference model. (OSI is a standard from the International Organization for Standardization; it divides into seven layers the functions involved in the interchange of information among very different end systems, such as networks, computers, and workstations.) T1 multiplexers allow an enterprise's LAN and private-branch-exchange (PBX) subnetworks to share the same backbone trunk facilities through the use of time-division multiplexing techniques. But if the LANs to be linked use different protocols (such as token ring, Ethernet, or FDDI), then they need other LAN interconnect products—the bridges, routers, and gateways—to convert those protocols.

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BRIDGES. Bridges use the bottom two OSI layers (the physical and data link, including a LAN's logical link control and media access control layers) to interconnect two LANs that usually have identical protocols at those two layers. This generally implies that the two LANs conform to at least one of these standards: IEEE 802.3, 802.4, 802.5, or FDDI. Moreover, the OSI network layers 3–7 must be identical in the end stations (PCs or host computers) for successful end-to-end communications [Fig. 1].

A bridge does not look at—is transparent to—higher-layer protocols; it is up to the end stations to translate received information. Therefore, the bridge is much simpler to design than a router or gateway.

A bridge relays packets between LANs by storing and forwarding them. The few bridges that interconnect dissimilar LANs perform the necessary protocol conversion on reformatted packets.

A bridge that does not perform protocol conversion need modify neither the formats nor the contents of the packets it routes between LANs, thanks to the networks' identical protocols.

Some bridges require only a manual routing table approach (also called fixed routing). But those with greater intelligence are capable of acquiring a routing table and updating it through the automatic process of continuous learning.

Both the IEEE 802.1 group and IBM Corp. have developed routing specifications. The IEEE's specification is based on a spanning-tree protocol (STP). STP defines the way a routing table within each bridge can be dynamically changed to eliminate loops or avoid malfunctioning routes by temporarily deactivating certain paths. Loops are not allowed within a bridged network because on a loop packets might circulate indefinitely or duplicate packets be received by the end stations.

But eliminating loops, as STP does, by avoiding some links could be an uneconomic use of that expensive resource, leased lines. Furthermore, after a network failure, STP can introduce significant, 1-minute delays, due to the time required for building a new spanning-tree routing table. Thus, although STP may be adequate for internets consisting only of local bridges, it does not allow for the many alternative routes that characterize the design of a true backbone network.

IBM's routing specification, the source routing protocol (SRP), allows each LAN station to append unique routing information to every packet. Each bridge complies with the path indicated for the packet. Originally the SRP was specified for internets with local single-port bridges; but some vendors have developed multiport routing bridges (also called brouters) that support the SRP technique. The number of brouters needed is fewer than the number of bridges.

Multiport remote bridges based on the STP routing scheme are marketed by some non-IBM vendors for non-IBM token ring internets. To make things easier for the user, a new IEEE 802.1 specification, source routing transport (SRT), attempts to merge both STP and SRP schemes for bridges. Here, a bridge would choose either the STP or SRP scheme by sensing a bit within the routing information field. If the end station sets the bit to 0, the bridge chooses STP; if to 1, then SRP.

ROUTERS. Employing the bottom three OSI layers, routers interconnect LANs running identical internetwork protocols [Fig. 2, top]. (The LANs need not be alike in other respects.) Managing traffic congestion is the router's big plus: it employs a flow control mechanism to direct traffic onto alternative, less congested paths.

OSI layer 3, the network layer, is the primary basis for router operation; this layer is generally called internet protocol (IP). The best-known IP, also called the DOD-IP, is a part of the TCP/IP suite (where TCP stands for transmission control protocol, and a suite is a unique set of standards or protocols). ISO has issued an OSI-IP standard (ISO 8473) that improves on the DOD-IP.

Within an enterprise-wide network, a router uses the protocol-sensitive information in a packet to determine how to route the packet. In a simple internet configuration, such as a star, each router maintains a static routing table. In a more complex configuration with several backbone subnetworks, well-designed routers maintain dynamic routing tables that reflect changing patterns of network failures and congested paths. The dynamic updating is done by the router exchanging what are called address-resolution packets with other routers in the network.

Packets may vary in size from one subnetwork to the next. For example, one common LAN, Ethernet, permits no packet longer

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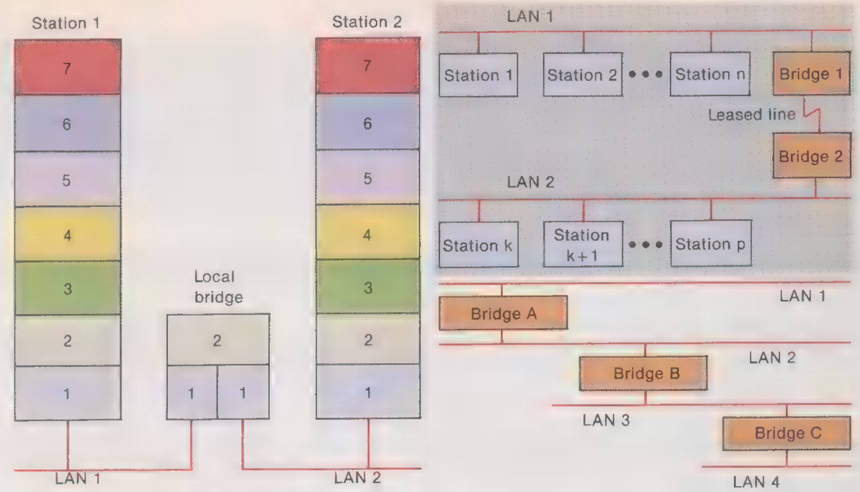


[1] Bridges usually interconnect LANs with identical protocols for the physical and data link layers (OSI layers 1 and 2 of the seven-layer stack). The bridge at left is called local because it interconnects two nearby LANs. With two LANs at some distance from each other, the interconnection is through two remote bridges and a leased line (top right); these remote bridges are sometimes called half-bridges or parts of a single remote bridge. Some multiport bridges can connect a LAN to two or more other LANs. When several bridges are employed to interconnect many LANs, each bridge must have enough intelligence to route a packet to the destination LAN via the shortest path (bottom right).

than 1500 bytes, while a typical X.25 network draws the line at 1000 bytes. That means a router may have to break up the packet into segments before transmitting the data to the next subnetwork. A router must also provide enough in the way of translation to accommodate the many interface differences, both hardware and software, associated with an internet's subnetwork.

To pick out the shortest path to a destination node, a router employs an algorithm. This algorithm becomes quite intricate in a configuration complex enough to require dynamic routing tables. Most routers, however, use the routing information protocol (RIP) algorithm. RIP computes the distance between a router and a destination node in number-of-hops units, but it ignores other attributes such as the capacity of each link (in bits per second) and the actual length of each hop (in kilometers or miles). Consequently, the path chosen may not be the best. Use of RIP in routers also adds to overhead: each is required to send a copy of its routing table to every neighboring router about once every 30 seconds. In a large configuration, consisting of links with capacities of 64 kb/s or lower, the additional traffic load may become too heavy.

To alleviate this network overhead, a user can employ one of two methods. The first is to use fewer table updates; but this delays the router's reaction to network failures or congestion. The second is to send copies of the routing table only when changes occur in the state of a link. A newly proposed standard, called open shortest path first (OSPF), incorporates the second method, replacing RIP. OSPF also takes other link attributes, such as capacity and congestion, into account in choosing a route. Several vendors have already introduced products based on OSPF. With additional logic, and in case of link failure or congestion, a router can either drop packets or, better still, inform the source to slow down.

GATEWAYS. With dissimilar LANs that employ different high-level protocols, such as TCP/IP, DECnet, and SNA (systems network architecture), a gateway translator appears to be the system of choice [Fig. 2, bottom]. A gateway encompasses all seven OSI reference model layers.

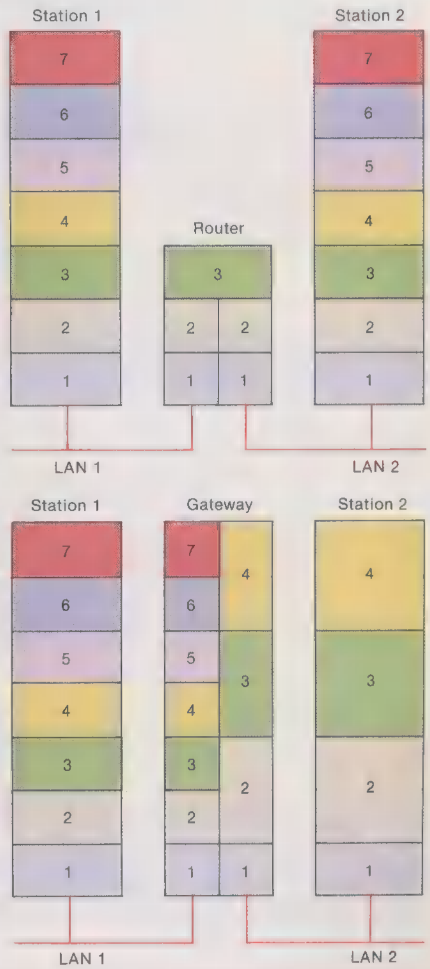
Although a gateway by and large costs more than a bridge or router, it can serve as a universal building block for an enterprise-wide network composed of a good many widely scattered and dissimilar LANs. Gateways are also an excellent way to migrate toward OSI.

BACKBONES. The next step up is a backbone network for several LANs. They may be interfaced to, for example, a metropolitan-area network (MAN) by specially designed bridges and routers. MANs are based on standards like FDDI and IEEE 802.6. IEEE 802.6 LAN-based products will allow integration of voice, data, and video applications and ultimately be able to span wider areas than FDDI products.

Other products still only in early development are based on the fast packet and cell relay technologies. Both types will provide end-to-end switched delivery of packets of variable length. Fast packet switching minimizes the flow-control and error-checking overhead of traditional packet switching. Cell relay divides packets into short, fixed-length segments to provide for switching of combined voice, data, and video traffic. Cell relay operation for MANs or WANs can be based on IEEE 802.6 or on asynchronous transfer mode (ATM). These embryonic products will allow LAN internetworking to adopt an on-demand stance toward bandwidth—a feature they will share with products based on the up-and-coming synchronous optical network (Sonet) carrier standard, which has a data rate of 155 Mb/s initially, 1.2 Gb/s later on [''B-ISDN and how it works,'' pp. 35–8].

NETWORK PLANNING. About 25 percent of existing LANs are interconnected. This implies a tremendous growth potential in LAN-WAN integration. When an enterprise decides to weave all its LANs into a WAN spanning a metropolitan area or even an entire country, in-depth network planning becomes mandatory. After all, transmission facilities account for about 75 percent of the monthly communications cost of a typical enterprise's network. Users should therefore tie their network planning in closely with their constantly updated databases as part of the network management and control effort.

TRANSMISSION FACILITIES. Critical to LAN internetworking on this scale is the availability of leased lines or virtual-circuit ser-



[2] Routers interconnect similar or dissimilar LANs running identical internetwork protocols (top). A gateway is the system of choice for linking LANs that are unalike and employ different protocols. Here (bottom in figure), two end systems, one with a seven-layer OSI reference model and the other with a four-layer TCP/IP reference model, communicate through a gateway that translates each protocol into the other.

Representative systems for interconnection of local-area networks (LANs)[1]

Number of ports	Intercon-nect standard	Max. aggregate rate supported (all ports), Mb/s	Routing scheme	Protocols supported	Network operating system supported	Wide-area network interface	Comments
ACS 4200 (bridge or router or both), 1991, Advanced Computer Communications Inc., $8500							
3	802.3	2.48	RIP, OSPF, EGP	TCP/IP, DECnet, IPX, XNS	N.A.	RS-232, RS-422, X.21, X.25, V.35, T1	—
MLB 1033 (bridge), 1989, Alantec, $13 000–$25 000							
2–10	802.3	40 (up to 160)	STP	N.A.	N.A.	V.35, T1, fractional T1	Able to filter (logically) any part of a packet
Bridgeport 7606 (bridge), 1989, Andrew Corp., $3995–$5695							
2	802.5	16	Source routing	Token ring	Netware; IBM PC LAN Server; 3 Com Open; Banyan Vines	T1 (9.6 kb/s–2.048 Mb/s)	—
LANcity (bridge), 1986, Applitek Corp., $13 150							
2	802.3	10	Transparent	All	N.A.	MAN, CATV system	10 Mb/s in 6-MHz MAN bridges over cable TV systems
Galactica StarBridge/82, [illegible], 1991, Artel Communications Corp., $18 500							
8 (up to 32)	802.3	80 (up to 320)	Closed user groups	OSI	All	N.A.	Modular multipart bridge
T/200 IPR (bridge and router), 1990, BBN Communications Corp., $10 000–$35 000							
2–52	802.3, 802.5, FDDI, T1/E1/frac-tional T1	100 (or 6 for [illegible] WAN)	RIP, OSPF, EGP	TCP/IP, DECnet, IPX, XNS, AppleTalk, X.25, frame relay, bridging	N.A.	X.25, T1, E1, fractional T1, synchronous lines, frame relay, SMDS	—
FDDI 1420 (bridge), 1990, BICC Communications, $27 500							
2	802.3, FDDI	100	STP	N.A.	N.A.	N.A.	—
ONline Ethernet Router Module (router), 1991, Chipcom Corp., $6350–$7150							
2	802.3	10	STP	TCP/IP, DECnet, XNS, AppleTalk, IPX, Apollo Domain, Banyan Vines	Netware, MS-NET, Banyan Vines	X.25, T1, frame relay	—
AGS+ (router), 1990, Cisco Systems Inc., $12 300 and up							
28	802.3, 802.5, FDDI	38.4	STP and source routing (when bridging)	16, incl. TCP/IP, DECnet, XNS, IPX, AppleTalk, OSI, Apollo Domain	N.A.	X.25, multiple T1, E1, fractional T1, 56 kb/s, frame relay, SMDS	Supports multiple routing protocols and multiple media, concurrently, and up to 4 FDDI interfaces
ET/Bridge (bridge or router), 1989, Emerging Technologies Inc., $1495							
5	802.3	50	IP	IP	N.A.	X.25, T1, DDS, dial-up	Employs data compression
Ringmaster 7200 (bridge), 1990, FiberCom Inc., $8500 per port							
[illegible] (incl. FDDI)	802.3, 802.5	100	STP (per 802.1d)	Transparent	N.A.	N.A.	—
TDMR-560, 1988, FiberLAN Inc., $25 000							
12	T3	45	External router used	All	All	All	WAN over single-mode fiber up to 40 km
FX5510T (bridge), 1989, Fibermux Corp., $22 000–$25 000							
1	802.5, FDDI	100	Source routing	Token ring	All	None	—
Connect LAN 200 Series (bridge), 1990, Halley Systems Inc., $6995–$11 500							
1–3	802.5	12	Source and nonsource routing	All	N.A.	RS-449, V.35, RS-422, E19.2 to T1, E1	Employs data compression
Supernet X (bridge), 1991, Harris Adacom Corp., contact vendor							
4	802.2	512 kb/s	Source routing, STP	TCP/IP	N.A.	X.25, SDLC	—
MLB 6000 (bridge), 1987, Microcom Inc., $3399–$13 895							
5	802.3, 802.5	8	Source routing, STP	All	All	X.25, fractional T1, T1, ISDN	Achieves 4:1 data compression over any speed link
TokenMaster 400 (bridge), 1989, Netronix Inc., $4900–$7600							
2	802.5	2.048	Source routing	All	N.A.	T1, fractional T1, DDS	Employs WAN data compression
Adapt SNA LAN Gateway (gateway), 1989, Network Software Associates Inc., $3995							
N.A.	802.2, 802.3, 802.5	16	Source routing	IPX/SPX, NetBIOS, SNA	IBM, Netware 3+, LAN Manager 2, Banyan Vines	X.25	Product has no network management

Representative systems for interconnection [illegible] local-area networks (LANs)[1] (continued)

Number of ports	Interconnect standard	Max. aggregate rate supported (all ports), Mb/s	[illegible] scheme	Protocols supported	Network-operating system supported	Wide-area network interface	Comments
6800 [illegible] (bridge or router), 1991, [illegible]							
1 (T3), 4 (Ethernet)	802.3	800	Spanning tree, learning bridge, source routing (R)	TCP/IP, DECnet, IPX, XNS, AppleTalk Phase I, independent bridging	"Hello" (TCP/IP), RIP, EGP	T1, T3, multiple link-layer interfaces, PPP, frame relay, DX link, SMDS, LAPB	Provides traffic statistics; optional director host attachment, channel extension, SNA support, and connections to 6.4- and 25.6-Gb/s HiPPI switch; T3 or multisynchronous V.35 ports
[illegible] Novell [illegible], $2995							
Up to 128 sessions	802.3, 802.4, 802.5	64 kb/s	N.A.	IPX/SPX	Netware 2.15 and above	N.A.	—
[illegible] Rabbit [illegible]							
N.A.	802.2	16	Source routing	SNA, IPX, NetBIOS	IBM, Novell, Banyan, others	N.A.	Includes line monitor, gateway LV monitor, line trace, APIs, scripting, keyboard template
RTB 40 [illegible], 1989, RAD [illegible], $8450							
5	802.5	3	Transparent OSPF and source routing	N.A.	N.A.	T1	—
[illegible] 3Com Corp., [illegible]							
2	802.3	9500 packets/s	Spanning tree	CMOT, SNMP, bridges all protocols	Netware, LAN Manager, 3+, and others	RS-232, V.35	No restrictions with network operating systems
ASM 8300 (bridge or [illegible])							
3	802.3	10	Station load balancing	IP, XNS, DECnet, AppleTalk, X2	N.A.	X.25, RS-232, V.35, RS-422, RS-449, K.21, 9.6 kb/s–2.048 Mb/s (T1/E1)	Concurrent multiprotocol bridging and routing
LinkNode (bridge or router), [illegible] Wellfleet Communications Inc., [illegible] 500							
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in and among enterprises. At
oublic offering will be confined
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of 161 local U.S. telephone
on after, carriers are expect-

of 64 kb/s, T1 is 1.544 Mb/s, and T3 is 44.736 Mb/s. Some of these transmission services are—or will be—also available as switched services.

SWITCHED SERVICES. The contenders here are three: DDS, frame relay, and switched multimegabit data service (SMDS). Sever-

vice offers connectionless (having no need of fixed or virtual paths) packet transport, presently at T1–T3 access speeds but with 155 Mb/s promised. Unlike the FDDI MAN standard, SMDS has no distance constraints. (Bell Communications Research—BellCore—developed SMDS service and

ed to offer SMDS for nationwide enterprise networks. (There is no equivalent of the LATA in Europe, where most telephone companies are government agencies.)

Frame relay and SMDS both trim a network's transmission costs: they eliminate many point-to-point circuits through band-

Representative systems for interconnection of local-area networks (LANs)[1]

Number of ports	Interconnection standard	Max. aggregate rate supported (all ports), Mb/s	Routing scheme	Protocols supported	Network operating system supported	Wide-area-network interface	Comments
ACS 4200 (bridge or router or both), 1991, Advanced Computer Communications Inc., $8500							
3	802.3	2.48	RIP, OSPF, EGP	TCP/IP, DECnet, IPX, XNS	N.A.	RS-232, RS-422, X.21, X.25, V.35, T1	—
MLS 1033 (bridge), 1989, Alantec, $13 000–$25 000							
2–10	802.3	40 (up to 160)	STP	N.A.	N.A.	V.35, T1, fractional T1	Able to filter (logically) any part of a packet
Bridgeport 7606 (bridge), 1989, Andrew Corp., $3995–$5695							
2	802.5	16	Source routing	Token ring	Netware; IBM PC LAN Server; 3 Com Open; Banyan Vines	T1 (9.6 kb/s–2.048 Mb/s)	—
LANcity (bridge), 1986, Applitek Corp., $13 150							
2	802.3	10	Transparent	All	N.A.	MAN, CATV system	10 Mb/s in 6-MHz MAN bridges over cable TV systems
Galactica StarBridge/82, 3, 1991, Artel Communications Corp., $13 500							
8 (up to 32)	802.3	80 (up to 320)	Closed user groups	OSI	All	N.A.	Modular multipart bridge
T/200 IPR (bridge and router), 1990, BBN Communications Corp., $10 000–$35 000							
2–52	802.3, 802.5, FDDI, T1/E1/fractional T1	100 (or 6 for a WAN)	RIP, OSPF, EGP	TCP/IP, DECnet, IPX, XNS, AppleTalk, X.25, frame relay, bridging	N.A.	X.25, T1, E1, fractional T1, synchronous lines, frame relay, SMDS	—
FDDI 1420 (bridge), 1990, BICC Communications, $27 500							
2	802.3, FDDI	100	STP	N.A.	N.A.	N.A.	—
ONline Ethernet Router Module (router), 1991, Chipcom Corp., $6350–$7150							
2	802.3	10	STP	TCP/IP, DECnet,	Netware, MS-NET, Ban-	X.25, T1, frame relay	—
AGS+ (router), 1990, Cisco Systems In							
28	802.3, 802.5, FDDI	38.4					
ET/Bridge (bridge or router), 1989, Em							
5	802.3	50					
Ringmaster 7200 (bridge), 1990, Fiber							
5 (incl. FDDI)	802.3, 802.5	100					
TDMR-560, 1988, FiberLAN Inc., $25							
12	T3	45					
FX5510T (bridge), 1989, Fibermux Cor							
1	802.5, FDDI	100					
Connect LAN 200 Series (bridge), 1990							
1–3	802.5	12					
Supernet X (bridge), 1991, Harris Adac							
4	802.2	512 kb/s					
MLB 6000 (bridge), 1987, Microcom In							
5	802.3, 802.5	8					
TokenMaster 400 (bridge), 1989, Netronix Inc., $4900–$7000							
2	802.5	2.048	Source routing	All	N.A.	T1, fractional T1, DDS	Employs WAN data compression
Adapt SNA LAN Gateway (gateway), 1989, Network Software Associates Inc., $3995							
N.A.	802.2, 802.3, 802.5	16	Source routing	IPX/SPX, NetBIOS, SNA	IBM, Netware 3+, LAN Manager 2, Banyan Vines	X.25	Product has no network management

Representative systems for interconnection of local-area networks (LANs)[1] (continued)

Number of ports	Interconnect standard	Max. aggregate rate supported (all ports), Mb/s	Routing scheme	Protocols supported	Network operating system supported	Wide-area network interface	Comments
6800 Series (bridge or router), 1991, Network Systems Corp., $40 000–$100 000							
1 (T3), 4 (Ethernet)	802.3	800	Spanning tree, learning bridge, source routing (R)	TCP/IP, DECnet, IPX, XNS, AppleTalk Phase I, independent bridging	"Hello" (TCP/IP), RIP, EGP	T1, T3, multiple link-layer interfaces, PPP, frame relay, DX link, SMDS, LAPB	Provides traffic statistics; optional director host attachment, channel extension, SNA support, and connections to 6.4- and 25.6-Gb/s HiPPI switch; T3 or multisynchronous V.35 ports
Netware SNA Gateway, 1986, Novell Inc., $12995							
Up to 128 sessions	802.3, 802.4, 802.5	64 kb/s	N.A.	IPX/SPX	Netware 2.15 and above	N.A.	—
RabbitGATE Token-Ring (gateway), 1989, Rabbit Software Corp., $4995–$6995							
N.A.	802.2	16	Source routing	SNA, IPX, NetBIOS	IBM, Novell, Banyan, others	N.A.	Includes line monitor, gateway LV monitor, line trace, APIs, scripting, keyboard template
RTB 40 (bridge), 1989, RAD Network Devices, $8450							
5	802.5	3	Transparent OSPF and source routing	N.A.	N.A.	T1	—
IB/2000 Internetworking Bridge, 1989, 3Com Corp., $4495–$7445 ($250 software)							
2	802.3	9500 packets/s	Spanning tree	CMOT, SNMP, bridges all protocols	Netware, LAN Manager, 3+, and others	RS-232, V.35	No restrictions with network operating systems
ASM 6300 (bridge or router), 1991, Ungermann-Bass Inc., $4994–$7495 ($995 software)							
3	802.3	10	Station load balancing	IP, XNS, DECnet, AppleTalk, X2	N.A.	X.25, RS-232, V.35, RS-422, RS-449, K.21, 9.6 kb/s–2.048 Mb/s (T1/E1)	Concurrent multiprotocol bridging and routing
LinkNode (bridge or router), 1989, Wellfleet Communications Inc., $11 500							
8 (16 for WANs also)	802.3, 802.5, FDDI	116 000 packets/s	RIP, OSPF	TCP/IP, DECnet, IPX, XNS, SRT, X.25, AppleTalk, SDLC, IEEE STP	N.A.	RS-232, X.25, V.35, T1, E1, frame relay, SMDS, high-speed private-line fractional T1	Concurrent multiprotocol routing and bridging
XLNT Concentrator, 1990, XLNT Designs Inc., depends on configuration							
2 or more	FDDI	100	N.A.	TCP/IP, SNMP	N.A.	N.A.	XDI licenses the design of this product for manufacture
MAXserver 6820 (bridge), 1991, Xyplex Inc., $4495							
2	802.3	1.544	IEEE spanning tree	All 802.3 Ethernet protocols	N.A.	RS-422, RS-423, V.35, 9.6 kb/s–1.544 Mb/s or E1, 2.048 Mb/s	Works with VitaLink bridge and bridge routers

1. Year product first available

Key

API: application programming interfaces.
AppleTalk: protocol by Apple Computer.
CMOT: common management information protocol over TCP/IP.
DX: duplex signaling, a signaling system that shares a cable pair with a voice path and does not require a filter.
EGP: exterior gateway protocol.
FDDI: fiber-distributed data interface.
HiPPI switch: high-performance, parallel interface switch.
IPX: internetwork packet exchange (Novell).
ISDN: integrated-services digital network.
LAPB: link-access procedure, balanced.
MAN: metropolitan-area network.
N.A.: not applicable.
NetBIOS: network basic input/output system (IBM).
OSI: open systems interconnection.
OSPF: open shortest path first.
PPP: point-to-point protocol.
RIP: routing information protocol.
SDLC: synchronous data link control (IBM).
SMDS: switched multimegabit data service.
SNA: systems network architecture (IBM).
SNMP: simple network management protocol.
SPX: sequence packet exchange (Novell).
SRT: source route transparent.
STP: spanning-tree protocol.
TCP/IP: transmission control protocol/internet protocol.
WAN: wide-area network.
XNS: Xerox network systems.

vices. A virtual circuit is provided by a public-switched-network carrier; without being an actually continuous, physical transmission path, it behaves like one, even to having such leased-line capabilities as conditioning and testing.

Most common carriers offer point-to-point leased lines for use in designing a WAN. These offerings are varied: voice-grade extends up to about 4 kHz analog; Dataphone Digital Service (DDS) ranges over 2.4–56 kb/s; fractional T1 (FT1) comes in multiples of 64 kb/s, T1 is 1.544 Mb/s, and T3 is 44.736 Mb/s. Some of these transmission services are—or will be—also available as switched services.

SWITCHED SERVICES. The contenders here are three: DDS, frame relay, and switched multimegabit data service (SMDS). Several carriers already have circuit-switched digital data services at speeds up to T1. Some have also announced private virtual-circuit frame-relay services. In effect an upgrade of X.25 packet switching, frame relay has a somewhat different frame format and is faster—fewer error-checking procedures give it a speed of 56 kb/s, with an increase to T1 expected later.

Trials of SMDS have also been announced by most regional Bell holding companies (RBHCs). The public packet-switched service offers connectionless (having no need of fixed or virtual paths) packet transport, presently at T1–T3 access speeds but with 155 Mb/s promised. Unlike the FDDI MAN standard, SMDS has no distance constraints. (Bell Communications Research—BellCore—developed SMDS service and equipment requirements for the public carriers.) The protocol for accessing it is defined in the IEEE 802.6 MAN standard.

SMDS will make broadband connections economical among widely scattered LANs. With its publicly available addressing scheme, SMDS will provide communications both within and among enterprises. At first, the 1991 public offering will be confined to a local access and transport area (LATA) served by one of 161 local U.S. telephone companies. Soon after, carriers are expected to offer SMDS for nationwide enterprise networks. (There is no equivalent of the LATA in Europe, where most telephone companies are government agencies.)

Frame relay and SMDS both trim a network's transmission costs: they eliminate many point-to-point circuits through band-

LAN INTERCONNECTION: WIDE-AREA DATA NETWORKS

Interconnecting local-area networks (LANs) across wide areas can be done in one of three ways—with a packet-switched public data network (PSPDN), internet services, or dedicated digital lines.

In the United States, PSPDN services are offered commercially by such carriers as US Sprint (formerly Telenet), BT Tymnet, CompuServe Inc., and the regional Bell holding companies. In other countries, the national telecommunications administrations offer them.

The PSPDN model cannot handle computer-to-computer communications within a LAN because the sporadic bursts of LAN traffic are typically over before a PSPDN can set up a virtual call. (A virtual call looks to the user like a pre-existing end-to-end circuit.) Conversely, a LAN does not establish a LAN-to-LAN connection. Instead, the LAN's transmission mechanisms address and route each packet independently. These connection-independent and hence connectionless packets are called datagrams.

When a datagram arrives on the LAN, a router makes a virtual call to the PSPDN destination indicated and forwards the packet. The router must then balance two conflicting requirements: it should retain the established call to avoid set-up delays for any later packets, yet, because PSPDN charges are often based on how long a connection lasts, the router should clear the call as soon as possible.

One dodge is the use of a permanent virtual circuit between any two points on the PSPDN. Such a circuit is a virtual call whose logical connection remains in force even after a call is completed. This is overkill, however—it eliminates not only time-sensitive charges, but also the ability to communicate spontaneously with anyone else on the PSPDN, unless, of course, the user resorts to multiplexing at the interface.

Elaborate error-correction mechanisms operate across every PSPDN link, to the detriment of throughput. Fiber transmission lines induce by far the fewest errors, and when they are used with end-to-end (user-to-user) error correction, link (node-to-node) error-correction mechanisms become much less necessary. (A node is an intermediate computer system in a network transmission path.)

One new U.S. carrier offering, frame relay, is essentially a PSPDN service over permanent virtual circuits, but stripped of all error correction. Switched virtual calls for frame relay are under study.

ONE INTERNET. The National Science Foundation's NSFNET links over 20 regional U.S. networks—at 44.736 Mb/s (T3) by the end of 1991—as well as networks in other countries. NSFNET was introduced in 1986.

NSFNET's U.S. regional networks in turn link hundreds of campus networks, serving hundreds of thousands of computers. LANs, dedicated digital lines, even PSPDN services are interlinked by routers to form a network of networks: the Internet. The internet protocol (IP) is generally used with the transmission control protocol (TCP) to provide end-to-end error correction.

SWITCHED DIGITAL LINES. To support datagram-based internets for commercial, research, and education users, carriers in the United States, Australia, and Europe are introducing switched multimegabit data service (SMDS) and comparable services. *—Larry Lang*

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width sharing, and SMDS also includes switching. The combined use of fast packet switching, ATM, and Sonet technologies will achieve additional cost reductions.

Across the Atlantic, the European Telecommunications Standards Institute (ETSI) has adopted the IEEE 802.6 standard as the basis for its work on MANs. As a result, 14 European countries are scheduled to conduct trials of SMDS-like services during the next two years. (British Telecom plans to conduct a service trial in London in 1991.) With these activities, SMDS appears to offer the basis for future international enterprise networks.

Linking LANs threatens network security with unauthorized reading and malicious alteration of key data. To keep data private, either access to the data must be restricted or encryption techniques must be used. However, the stricter the access control, the less friendly the system is to users, so a balance must be struck.

NETWORK MANAGEMENT. Management of faults, accounting/billing, configurations/inventory, performance, and security are the chief elements of OSI's network management architecture. Additional elements such as software management, ongoing network planning, and employee training may be added to that list, as required. And most vendors provide good solutions for network management of their own LANs. But the picture is very different when the LANs in a WAN are from different vendors and handle different protocol suites. Then WAN management can become well-nigh impossible.

Yet obviously the departments of an enterprise generally acquire their LANs long before the decision is made to integrate the LANs into a manageable WAN. Since it is seldom practical to uproot the installed LANs and start all over with a single network management architecture, the enterprise must select a migration path toward a single, unified approach to network management. Users of TCP/IP can select the simple network management protocol (SNMP), then upgrade to ISO's full common management information protocol (CMIP) once it becomes available.

At least three prominent vendors—AT&T Co., IBM Corp., and Digital Equipment Corp.—offer network management architectures that should satisfy the needs of even the most exacting user. They all appear destined eventually to support the final OSI network management standard.

AT&T's UNMA provides end-to-end network management in a multivendor environment. It is based on the OSI model and its associated standards. UNMA is a three-layered framework consisting of network elements, element management systems (EMSs), and integrated network management systems (INMSs). Each element represents a managed device such as a modem, LAN, PBX, or host; each EMS manages a set of network elements; and each INMS provides an end-to-end view at a network control point. Two Accumaster Integrator products represent AT&T's entry into the INMS line. As for EMSs, AT&T offers about 20 (such as StarGroup for the company's StarLAN), and more than 50 vendors have agreed to develop EMSs and to test their compatibility with Accumaster Integrator.

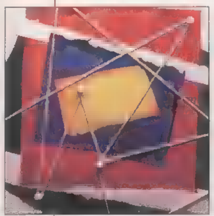
IBM's newly introduced SystemView architecture embraces Big Blue's open network management (ONM) structure, implying that SystemView will ultimately support IBM's leading network management product, NetView. (Another implication is that SystemView may also encompass IBM's LAN Manager for token ring LANs.) Lending credence to this view, today's NetView is being extended to handle OSI and TCP/IP, besides the SNA environments. Furthermore, SystemView allows multivendor application interfaces such as LU6.2 (IBM's logical unit 6.2, an application-to-application *de facto* standard). This capability will some day allow other vendors to communicate with the host-based SystemView software in multivendor environments.

DEC's Enterprise Management Architecture (EMA) is much like IBM's SystemView. It embodies DEC's commitment to the management of heterogenous, multivendor, distributed computing environments and all the communications facilities that let them communicate. It will support the company's own DECnet/OSI Phase V and DECnet Phase IV, as well as TCP/IP, Ethernet, bridges, terminal servers, and FDDI products. Many vendors have agreed to fit their products under the EMA umbrella.

ABOUT THE AUTHOR. Roshan L. Sharma is an independent consultant specializing in telecommunications and network science. He spent 32 years with Rockwell International Corp.'s Collins Radio Group doing pioneering work in telecommunications, data and voice digital switches, and network science. He has written over 100 technical papers and two books and has directed numerous seminars. For several years, he represented Rockwell International at CCITT-sponsored meetings in Washington, D.C., and Geneva, Switzerland. He received a B.A. in physics and mathematics from the Punjab University in India and an M.S. in physics from University of Southern California, Los Angeles.

B-ISDN and how it works

End users will get multimedia transmission by accessing gigabit-per-second public networks on a switched basis



Sending data over long distances will soon be handled faster than most of today's local transmissions. Although a design engineer living in Paris today can discuss a simulation experiment with a co-worker in Grenoble by sending the design over a data communications network, it may not be done as efficiently or cheaply as the two might wish. A new kind of network is emerging, however, that will reduce the cost of long-distance high-speed data transfer by enabling users to share expensive high-bit-rate public transmission resources.

The main elements of the new networks will be based on a series of emerging international recommendations known as broadband integrated-services digital network (B-ISDN). The series is being developed by the International Telegraph and Telephone Consultative Committee (CCITT) to describe techniques for packet-switching data, voice, and video at very high speeds.

Currently design engineers have two basic transmission options to send graphics images. One is using public switched transmission links at speeds of 64 kilobits per second employing either narrowband ISDN (N-ISDN) or X.25 packet switching. This choice provides only a relatively low bit rate and has a high transit delay (which to the end user looks like a long response time). The second option is using leased lines that offer up to 34 megabits per second in Europe and 45 Mb/s in the United States. But this choice has several drawbacks.

For example, if the engineers choose leased lines (which are dedicated data communications links running between two prespecified locations), they will also have to maintain voice links through the telephony network.

Leased lines pose an additional problem because customers are billed on the basis of a line's capacity rather than its usage. Although packet-switched networks overcome this problem by providing, through one connection to the network, virtual connections to all the users, they do not support telephony. Moreover, commercial availability of packet-switched networks offering 34 or 45 Mb/s is not widespread.

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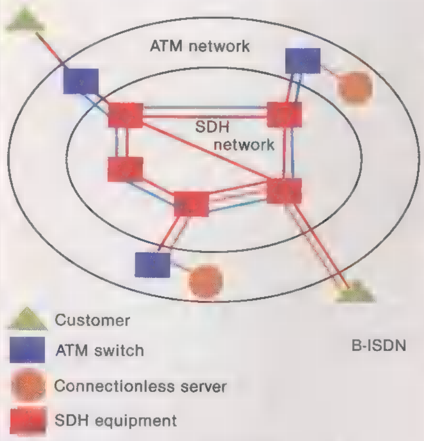
By contrast, networks based on B-ISDN will carry design simulations and other multimedia transmissions that include text, voice, video, and graphics. They will provide end users with increased transmission rates (up to 155.52 Mb/s initially) on a switched basis. That means an engineer can have multiple virtual connections to disparate locations with just one link to the network.

To provide these benefits, the public network will have internally (that is, within the network as opposed to the periphery of the network, which meets the customer's premises) a transmission capacity of 622 Mb/s, 1.244 gigabits per second, and 2.488 Gb/s [Fig. 1]. These bit rates derive from



[1] Broadband integrated-services digital network uses optical-fiber synchronous digital hierarchy (SDH) equipment plus asynchronous transfer mode (ATM) switching to link users over long distances. The concatenation of ATM equipment and a connectionless server may be considered analogous to the metropolitan-area network switching system defined in the switched multimegabit data service.

specifications that were adopted by the CCITT in the recommendation called synchronous digital hierarchy (SDH). Referring to synchronous (as opposed to today's more commonly used plesiochronous) data transmission over optical-fiber cable, SDH evolved from a family of standards that were originally proposed by Bell Communications Research Inc. (now BellCore) and that later became known as Sonet, or synchronous optical network. The terms are sometimes used synonymously.

SDH describes the transmission medium over which B-ISDN will operate. The optical-fiber cable offers such a large amount of bandwidth that it could accommodate even 100-Gb/s transmission—and such network alternatives are being studied now [''Gigabit networks,'' p. 40].

FUNDAMENTAL DIFFERENCES. B-ISDN differs from N-ISDN in three key areas:

- N-ISDN makes use of the infrastructure of the telephony network as it exists today, using symmetrical copper wire pairs; B-ISDN uses optical-fiber cable.
- N-ISDN is mainly a circuit-based network and performs packet switching only on the D channel, which is used for signaling; B-ISDN uses only packet switching.
- N-ISDN channel bit rates are prespecified: for example, 16 kb/s (the D channel) and 64 kb/s (either B or D channels). In contrast, B-ISDN makes use of virtual channels, without any prespecified bit rate. The only bit-rate limitation of the virtual channels is the physical bit rate of the user-to-network interface (which can be either 155.52 Mb/s or 622.08 Mb/s).

It is commonly agreed that data—rather than voice—services will play the major role in introducing B-ISDN throughout the world. Network service providers such as France Telecom, AT&T, British Telecom, MCI, and NTT are working along with the CCITT, the IEEE, and the European Telecommunications Standards Institute (ETSI) to determine which data services will lead the way.

A crucial decision was made in 1988 when the CCITT decided to base the development of B-ISDN on a switching technique known as ATM (asynchronous transfer mode). That decision was confirmed by a first set of recommendations in 1990. The term ATM is even now sometimes used as a synonym for B-ISDN.

ATM BASICS. One of the fundamental principles of B-ISDN, as well as N-ISDN, is to offer the subscriber (or end user) a large variety of services—each of which may require a different bit rate—through a single access point to the network. Thus a technique was needed to switch information flows that have time constraints relating to video or voice

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Gigabit networks

Digital transmission systems with speeds in excess of a gigabit per second have been in operation for several years—but only at the infrastructure of some facilities within the telecommunications industry. These installations are heavily multiplexed, and the end users typically obtain data rates in kilobits or megabits per second.

Now gigabit testbeds being established in the United States, supported by funding from the National Science Foundation (NSF) and the Defense Advanced Research Projects Agency (Darpa), are about to change that situation dramatically. The Corporation for National Research Initiatives (CNRI) is coordinating these efforts under a cooperative agreement with the Government.

The testbeds—known as Aurora, Blanca, Casa, Nectar, and Vistanet—will explore how users might benefit from gigabit-per-second speeds and will help evaluate the technology options for building such networks on a national scale. Participating telecommunications service carriers include AT&T, MCI, GTE, and the regional Bell holding companies. Joining in the research are IBM Corp. and BellCore, along with a number of universities, NSF supercomputer puter centers, and national research laboratories.

Topics to be examined include protocols, interfaces, switching, local distribution, and application environments—as well as asynchronous transfer mode and packet transfer mode for switching. The high-performance parallel interface is being used in the testbeds, and other interfacing strategies are being explored. Carriers in several of the testbeds are also providing synchronous optical network (Sonet) transmission.

Various applications that might be run on gigabit-per-second networks have been proposed as candidates for evaluation. Among them are concurrent computing of highly interactive distributed programs running on geographically separated supercomputers, synchronization and visualization of high-speed data, and real-time processing of partitioned graphics computations. A major performance consideration is how to cope with the network latency due to speed-of-light signal propagation.

The efforts undertaken for this project are part of the research that will lead to a nationwide network that operates at gigabit speeds. President George Bush's 1992 budget request to the Congress included funding for a new program called High Performance Computing and Communications. Research to develop the gigabit-per-second network is one element of that program. —*Robert E. Kahn*

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signals as well as information flows that are more sporadic and have widely variable bit rates.

Asynchronous transfer mode meets these requirements. It is a hybrid technique that combines the simplicity and the very high bit rates of circuit switching (currently used largely for telephony or video transmission) with the flexibility of X.25 packet switching (used for data).

In ATM, the basic unit of data transfer is called the cell [Fig. 2], which is processed at several stages throughout the network: by the terminal, the multiplexers, the cross-connects, and other switches.

The cell is a packet having a fixed, predetermined length with a header (including routing information used by the network) and an information field. The fixed format of the two fields assures that the processing may be done by a simple hardware circuit, thus enabling faster processing speeds than do software implementations.

Intended to support a wide range of communication services, ATM is designed to provide a transfer that is independent of these services in several ways. An example is time independence, where no relationship exists between the application clock and the network clock. Another is semantic independence, whereby the network information unit (the cell) and the unit of application information are not related. This results in a transfer protocol unit in which the header is used only for network transfer functions. The ATM network does not process the information field; in particular, it provides no error checking.

Cells are multiplexed asynchronously. That is, the various streams of assigned (information-carrying) cells are queued before being interleaved over a transmission resource. The bit rate of the aggregate assigned cell stream is adapted to the transmission rate (but should never exceed that rate) by inserting idle cells. These are discarded when they reach the next destination node so that a continuous flow of cells is transported. To make ATM independent from any underlying transmission means, the receiving side recovers the cell boundaries from the bit stream that it receives by using a mechanism called cell delineation.

CHANNEL IDENTIFICATION. Cells belonging to a channel are identified by the virtual channel concept that is already used in X.25 networks. The identification is local to the multiplex (that is, the collection of information coming from a number of sources) and may be changed at each switching point.

The identifier consists of two complementary fields, known as the virtual path identifier (VPI) and the virtual channel identifier (VCI). At each interface, a communications channel is identified by the VPI and VCI combination. The concept of a virtual path was introduced to provide the capability to manipulate a set of up to 2^{16} ATM connections as one unique channel.

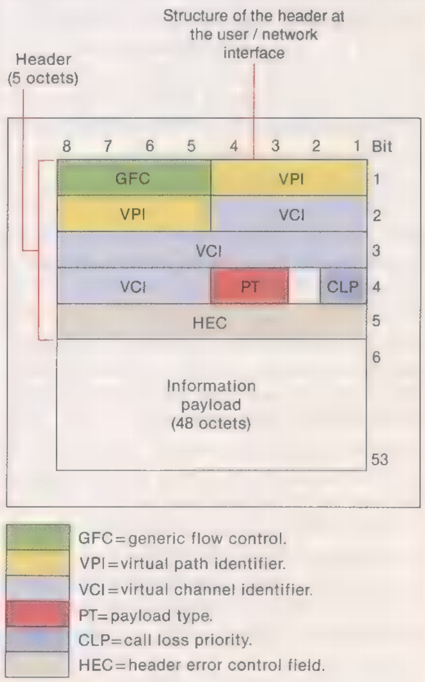
A switch making use of the full combination of VPI and VCI is called an ATM switch; while a switch that uses only the VPI is described as an ATM cross-connect.

One result of this routing method is that ATM becomes a connection-oriented technique requiring that a connection be set up before information is transferred to determine the routing and to map the incoming and outgoing virtual channels. Once the connection is set up, the switch analyzes the header; it also switches the cell from the incoming multiplexed stream to the predetermined outgoing multiplexed stream.

Although cells are switched individually, the integrity of the cell sequence is maintained by the switch. All switching actions operate at the cell rate, regardless of the channel rate. This allows the switching of cells belonging to different calls, each having a wide range of bit rates. It also supports the variable bit rates that come from sources having sporadic data flows.

In addition to the basic functions of ATM, some other features allow both end users and network operators to identify various types of information and levels of quality of service. For instance, semantic priority enables users to choose cells that may be discarded in case of network congestion. So far two levels of semantic priority have been adopted by the CCITT and are supported by a 1-bit field. The terminology for this feature, called loss priority or discard eligibility, is not yet widely agreed upon.

Payload type is another feature of ATM. It helps the user to distinguish between cells that carry user information and those that carry service information. The user can then create a subchannel, along the same path as the user information, to check whether the



[2] Because the ATM (asynchronous transfer mode) cell has a predefined length and prespecified field location, it simplifies the user-to-network interface and the associated processing of data.

Classification of services for the AAL*

Service features	Class A	Class B	Class C	Class D
Timing relation between source and destination	Required		Not required	
Bit rate	Constant	Variable		
Connection mode	Connection oriented			Connectionless

*AAL = ATM (asynchronous transfer mode) adaptation layer.

[3] Four types of network service classes have been identified by the International Telegraph and Telephone Consultative Committee. The goal is to achieve a common segmentation and reassembly (SAR) layer for each class of service, thus allowing a reduced set of chips to support the various services.

quality of service promised by the network operator is in fact being delivered.

At some point, the customer premises equipment must intersect with the ATM network. This juncture is defined by the CCITT in its B-ISDN access reference model, Recommendation I.413. Responsibility for the line termination—which is referred to as NT1 (Network Termination 1) and includes only transmission functions—is determined according to national regulations. For example, in Europe, it is under the purview of the network operator; in the United States, it is the responsibility of the user. NT1 is usually located on the customer's premises; terminals may be directly connected to it.

The CCITT has agreed on two different bit rates for the interfaces known as S_B (155.52 Mb/s) and T_B (622.08 Mb/s): Sonet optical carrier (OC)-3 and OC-12, respectively. Most of the study work being done in the CCITT is on the former.

For that rate, two types of physical layers have been defined and are receiving an equal amount of effort by such study groups as CCITT Study Group XVIII. One is ■ cell-based interface, where the cell multiplex (the collected information coming from a number of sources and multiplexed onto one transmission flow) completely fills the available bit rate and where all the management and monitoring functions are carried via specialized cells. The other is an SDH-based interface, where the cell multiplex is inserted in the virtual container. Here, one can use the management and monitoring capabilities of SDH.

GENERIC FLOW CONTROL. To ensure equitable shared access to the public network, a new standard is being developed. The problem that must be solved becomes apparent when multiterminal configurations are necessary at the user access point. The engineer in Paris, for example, communicating with his co-worker in Grenoble may need more than one terminal at each site: besides a data terminal, there might be a Unix server as well as a videotelephone and a plotter.

One solution to this networking problem might be to connect the local-area network (LAN) to ■ router through an ATM interface and an ATM videotelephone—both would be connected to ■ multiplexer, which thereupon could forward the information that has gathered on the T_B interface.

For a simpler solution, however, the CCITT is providing the design of the S_B interface so that the various terminals may share autonomously the access to the network. In the same way, the 802.3 interface provides a shared access to a router. Since it thus becomes mandatory to ensure that each terminal gets ■ fair opportunity for network access and a guaranteed access capacity, some kind of flow control must be provided.

Although the details of this control mechanism, called generic flow control (GFC), are still under study, a field has been reserved in the header to introduce such capabilities. One criterion has been agreed upon: it must allow for various interconnect schemes—whether the LAN is configured as a bus, ■ star, or a ring.

The S_B interface will thus provide the same functionality from the LAN to the network that is presently provided from the terminal to the LAN. Moreover, it paves the way for the multimedia applications of the future because it will allow for local calls—both for asynchronous data and for isochronous services—and it will provide access to the network without a router.

When this interface is defined, it will compete with 802.3 and fiber-distributed data interface (FDDI) by simplifying the connection to the network while offering the same functionality as an 802.3 bus (but with higher bit rates and the option to support multimedia traffic). Moreover, users may prefer to build their own internal communications facilities using the S_B interface terminals rather than terminals interfacing via 802.3 or FDDI.

USING THE TRANSFER MODE. Because asynchronous transfer mode is designed to be independent of the various communication services that may be using the network, it does not address problems that are specific to applications. For this work, an additional protocol layer, called the ATM adaptation layer (AAL), may be implemented by the end-user equipment. Or it might be incorporated into additional application-dependent switching equipment.

The AAL must achieve the complementary functions that make the data stream exchanged from end to end compatible with the requirements of the service considered [Fig. 3]. The AAL is, of course, only processed outside the ATM network boundaries.

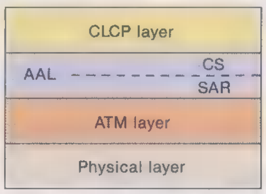
CCITT Recommendations I.362 and I.363 give the definition and the specifications of AALs. Two of these, in particular, concern data transfer. Type 3, for connection-oriented data transfer, will also be used for user-to-network signaling transfer; type 4 is for connectionless data transfer.

In developing the recommendations relative to AAL, the CCITT has concentrated on the connectionless mode transfer. The AAL developed for this mode of transfer is compatible with the connectionless mode transfer of the IEEE 802.6 standard.

Above the AAL on the protocol stack is a layer called the connectionless convergence protocol [Fig. 4]. This layer has not yet been firmly agreed upon by the CCITT, but it probably will be approved since it corresponds to the equivalent layer in SMDS (switched multimegabit data service)—layer 3. With this correspondence, a network can offer SMDS independently of the underlying technology. That is, it can be a network based on ATM or on IEEE 802.6.

It should be noted that ETSI is working toward the definition of a service that will be equivalent to and compatible with SMDS; it will be called CBDS (connectionless broadband data service). This service aims to be applicable both for metropolitan-area networks and for B-ISDN. The work is being done by the Working Party ETSI/NA5/MAN.

CONNECTIONLESS MODE. Since most LAN technologies today use connectionless mode, it seems logical to provide initially for a connectionless service that extends the local characteristic of the LAN through the public network and minimizes the router's functionalities. However, a connection-oriented mode is much better for a wide-area network because it helps optimize resource



CLCP = connectionless convergence protocol.
AAL = ATM (asynchronous transfer mode) adaptation layer.
CS = convergence sublayer.
SAR = segmentation and reassembly.

[4] The protocol stack for the application of connectionless services over an ATM (asynchronous transfer mode) network is shown here. The connectionless convergence protocol (CLCP) includes such network layer information as addressing information, carrier selection, and quality of service selection. The ATM adaptation layer (AAL) provides a service to the CLCP layer equivalent to the lowest part of high-level data link control (HDLC). This part involves message delineation, information transparency, and error detection.

1. B-ISDN switches: representative prototypes and products

Vendor	Product or prototype	Date available	Aggregate throughput, Gb/s	Type of switching fabric[1]	Bit rate, Mb/s	Phase of Sonet compliance
Digital Link Corp.	DL3000	Sept. 1992	1.2	ATM	155	II
GTE Laboratories Inc.	GTEL622A	Jan. 1992	10	OC-12 cross-connect	622	II
IBM Corp.	PiaNET	Dec. 1991	6	PTM and ATM	622	II
NEC America Inc.	NEAX 61E SMDS Service Node	1992	0.6	ATM and STM	OC-3 to OC-12	I
Northern Telecom	Anet	1993 or 1994	2 and up (modular)	ATM	622–2400	Up to III
Siemens Stromberg-Carlson	SSC ATM switch	1995	0.6	ATM	622	II
Thomson-CSF	Thompac 2G	1991	0.3–1.5	ATM	N.A.	N.A.

1. The way data is switched from one node to another within a network, rather than at the periphery.

Key

ATM: asynchronous transfer mode, by which fixed-length units of data, or cells, are transmitted in no particular or synchronized order.
B-ISDN: broadband integrated-services digital network (does not include multiplexers that use circuit multiplexing).
N.A.: not available.
OC-3: Sonet-compatible signal at 155.52 Mb/s.
OC-12: Sonet-compatible signal at 622.08 Mb/s.
PTM: packet transfer mode; the switch supports proprietary variable-size packets.
SDH: synchronous digital hierarchy.
Sonet: synchronous optical network.
STM: synchronous transfer mode.

2. Sonet ICs: representative prototypes and products

Vendor	Product or prototype	Date available	Phase of Sonet[1]	Comments
Amp Inc.	Gigabit/sec Optical Data Link	Feb. 1992	II	ECL (transmission)
AT&T Microelectronics	T7295	1991	I	CMOS (transmission)
France Telecom (Centre National d'Etudes des Télécommunications	COM 4	Oct. 1991	SDH-compliant	Switches up to 2500 Mb/s over 4 channels using ATM, CMOS
Hitachi America Ltd.	TRM/RCV 56XX and TRM/RCV 57XX	4th quarter, 1991	I and II	Silicon/optical (transmission)
Ipitek (Tacan Corp.)	Parsec	1991	II	ECL (transmission)
Olivetti Research Ltd.	CBN	1990	SDH-compliant	Switches up to 512 Mb/s over four channels using ATM and ECL
Philips Kommunikations Industrie AG	SLE-4	July 1991	SDH-compliant	CMOS, ECL, GaAs (transmission)
TriQuint Semiconductor Inc.	16G052/53 transmitter/receiver chip set	July 1991	I (OC-24)	GaAs, MESFET (transmission)

1. Phase I is 51.84 Mb/s; OC-24 is 1.244 Gb/s.

Key

ATM: asynchronous transfer mode. SDH: synchronous digital hierarchy. Sonet: synchronous optical network.

management and allows for much higher bit rates than are possible with connectionless mode technologies.

ATM networks do not process any information above the ATM level on the protocol stack, so they are essentially connection-oriented networks. But the information that is used for routing connectionless data (such as the destination address and the quality-of-service parameters that indicate cell loss and bit error rates) are located above this level. Thus, a new piece of equipment is necessary in the network: the connectionless server.

Subscribers to the connectionless service are linked to the connectionless server via an ATM connection at a peak bit rate, which is defined by the ATM connection, and at an average bit rate, which is controlled by the policing function included in the connectionless server. These servers are interconnected through ATM connections, building up an overlaid network that may be run by the ATM network operator or by a service provider that offers this value-added function.

With a connectionless server, there are several ways to design the switching and routing mechanism. The attractive feature is that all necessary information for routing is included in the first cell of the message. Reassembly of the message within a server is not necessary, which allows for a very short transfer delay within the network—giving users a very fast response time.

Transmission technology that uses single-mode optical fiber has progressed considerably in recent years, and capacity has reached 2.5 Gb/s per fiber pair. This capability, together with deregulation in the United States, has raised the problem of interconnection between network operating companies, particularly because the highest bit rate offered by an electrically standardized interface is only 45 Mb/s. At the same time, a demand has arisen for greater flexibility of the transmission technique to satisfy the business market.

These developments helped guide the definition of Sonet, which forms the basis of SDH. In addition to providing the Sonet capabilities, SDH offers highly sophisticated resources for managing the transmission network at its different levels. With such smart network management features, it is possible, for example, to dynamically modify the configuration of the multiplexers and to modify the line configuration.

The relationship between ATM and SDH has developed gradually. Today it is commonly agreed that SDH will be used for the network infrastructure, and that information conveyed by the SDH channel will use the cell ATM structure and be switched by ATM switches.

FIRST ATM SERVICES. Early implementations of B-ISDN and its underlying ATM technology are beginning to emerge, due to the interest and efforts of service providers and manufacturers of telecommunications equipment. [For products and prototypes that include B-ISDN features, see Tables 1 and 2.] Among the first services expected to make use of ATM are:

- A service permitting customers with the ATM cross-connect on leased lines to have any desired bit rate—from tens of bits per second up to 600 Mb/s—with a simplicity of reconfiguration that would be impossible with any other technology.
- A service allowing customers with ATM-based connectionless broadband data service (CBDS) to interconnect LANs (and in the near future MANs) at peak bit rates of more than 100 Mb/s. Sustained bit rates may be somewhat lower because of network management resource requirements.

These services will arrive sooner than others because they can proceed without the finalized version of the ATM signaling protocol—and because they address a business market, where the return on the investment may be quicker than it is in the larger market for public transmission services. These services represent a good starting point for the deployment of B-ISDN.

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Lionel Pelamourgues began working as a research engineer at CNET in 1986. He participates in the European Workshop for Open Systems Group for Lower Layers. His engineering degree is also from Ecole Nationale Supérieure des Télécommunications.◆

To probe further

High-speed local-area networks (LANs)

For background, an extensive review of low- and medium-speed LAN architectures and access protocols is found in the book, *Local Networks*, 3rd edition, by William Stallings (MacMillan, New York, 1991).

An excellent review of wireless LANs is presented in the paper, "Cordless Data Communications," by Frank Owen in *Cordless Telecommunications in Europe: The Evolution of Personal Communications*, ed. W. H. W. Tuttlebee (Springer Verlag, London, 1990).

A good reference on wireless LANs is the April 1991 special issue of the IEEE's *Communications Magazine* on intelligent buildings, particularly Thomas A. Freeburg's paper, "Enabling Technologies for Wireless In Building Network Communications—Four Technical Challenges, Four Solutions," Vol. 29, no. 4, pp. 58–64.

The areas of high-speed, supercomputer, and lightwave networks are surveyed in a paper by Imrich Chlamtac and William P. Franta entitled "Rationale, Directions, and Issues Surrounding High Speed Networks," in *IEEE Proceedings*, Vol. 78, no. 1, January 1990, pp. 94–120.

Additional material on lightwave networks can be found in the August 1990 issue of the IEEE's *Journal on Selected Areas in Communications* (JSAC), Vol. 8, no. 6.

Mario Gerla et al. wrote on "Buzz-Net: a Hybrid Token/Random Access LAN" in *JSAC*, Vol. SAC-5, no. 6, July 1987, pp. 977–88.

James F. Mollenauer's "Metropolitan Area Networks and ATM Technology" provides an especially good introduction to a related topic. His article appears in *International Journal of Digital and Analog Cabled Systems*, Vol. 1, no. 4, October-December 1988, pp. 223–28.

R. M. Newman et al. wrote about "The QPSX MAN," in IEEE *Communications Magazine*, April 1988. (QPSX is the prior name for distributed queue dual bus, or DQDB.)

Also see "An Overview of FDDI: The Fiber-Distributed Data Interface" by Floyd E. Ross in *JSAC*, Vol. 7, no. 7, September 1989, pp. 1043–51.

Fouad A. Tobagi dealt with "Expressnet: A High-Performance Integrated Services LAN" in *JSAC*, Vol. SAC-1, no. 5, November 1983, pp. 898–913.

B. Beach discusses in detail one of the supercomputer LANs in his "UltraNet: an Architecture for Gigabit Networking," which appears in the proceedings of the 15th Conference on Local Computer Networks, pp. 232–48. It was held in Minneapolis in October 1990.

Israel Cidon and Yoram Ofek gave a paper on "Meta Ring—a Full-duplex Ring with Fairness and Spacial Reuse" at IEEE Infocom '90, San Francisco, June 3–7, 1990, which was printed in the conference's proceedings.

For the same Infocom 90 conference proceedings, the authors of the current article, J. Bannister and M. Gerla, wrote "Topological Design of the Wavelength Division Optical Network," pp. 1009–13.

Another paper from the same Infocom 90 conference dealt with a reservation-strategy LAN: "Improving the Efficiency of DQDB Networks" by E. L. Hahne et al., pp. 175–84.

A popular network topology is assessed in "Performance evaluation of tree topology local area networks" by Flaminio Borgonovo, Enrico Cadorin, and Luigi Fratta, in the *Proceedings of the Ninth Conference on Measurements in Communication Systems*, October 1989.

Access to mesh networks is discussed in "Terabit Lightwave Networks: The Multihop Approach," by A. Acampora, in the *AT&T Technical Journal*, November/December 1987.

A good reference text on lightwave transmission is Joseph C. Palais's *Fiber Optic Communications*, Prentice Hall, Englewood Cliffs, N.J., 2nd edition, 1988.

A classic communications text with broader coverage than the previous one is A. Tanenbaum's *Computer Networks*, 2nd edition, Prentice Hall, 1988.

For background on multihop networks, see "[Shufflenet]: An application of generalized perfect shuffles to multihop lightwave networks," in the 1988 proceedings of IEEE Infocom, pp. 4B.4.1–12.

For background on token bus architecture, see "Description of FASNET, a Unidirectional Local Communications Network," by J.O. Limb and C. Flores, in the *Bell System Technical Journal*, Vol. 61, September 1982, pp. 1413–40.

The Manhattan street network is explained in greater detail by N.F. Maxemchuk in "Regular Mesh Technologies in Local and Metropolitan Area Networks," *AT&T Technical Journal*, Vol. 64, no. 7, September 1985, pp. 1659–85.

Interconnecting LANs

A tutorial, "Bridges and Routers" by William M. Seifert, appeared in the January 1988 issue (Vol.2, no.1) of the IEEE's *Network* magazine, pp. 57–64.

See also the January 1990 JSAC (Vol. 8, no. 1) on "Heterogeneous Computer Networks Interconnection," especially "Network Interconnection and Gateways" by Carl A. Sunshine, pp. 4–11.

A book that treats the internetworking of local- and wide-area networks is *LANs to WANs: Network Management in the 1990s*, by Nathan J. Muller and Robert P. Davidson (Artech House, Boston, 1990).

The IEEE held a workshop on interconnections within high-speed digital systems in Santa Fe, N.M., May 22–24. For more details, contact Gail Lalk, BellCore, 445 South St., Room MRE 2Q-144, Morristown, N.J.; fax, 201-984-0355.

The IEEE held its 10th Annual International Phoenix Conference on Computers and Communications in Scottsdale, Ariz., March 27–30. For further information, contact Oris Friesen, Bull HN, Box 8000, M/S A93, Phoenix, Ariz. 85066-8000; 602-862-5200.

The IEEE plans to hold a symposium on integrated-services digital networks in Tucson, Ariz., Dec. 8–12, 1991. Contact Russ DeWitt, Contel Service Corp., 245 Perimeter Center Parkway, Atlanta, Ga. 30346; 404-551-4911.

An XNS tutorial, "Understanding XNS: The prototypical internetwork protocol," by Bale Neibaur, appeared in the Sept. 21, 1989, issue of *Data Communications LAN Strategies* quarterly magazine, beginning on p. 43.

An article on "Multiwavelength Networks and New Approaches to Packet Switching" by Matthew S. Goodman appeared in the IEEE October 1989 *Communications Magazine*, Vol. 27, no. 10, pp. 27–35.

In a January 1991 editorial supplement to *Data Communications* magazine, Nick Lippis and James Herman provided an overview of internetworking devices and concepts in "The Internetwork Decade," from p. 52 on. (This supplement comprises excerpts from a lengthy study conducted by Northeast Consulting Resources Inc., Boston; 617-570-0780.)

One of three articles that discuss the various facets of the simple network management protocol (SNMP) is "SNMP Brings Order to Chaos" by Karyl Scott in the March 21, 1990, issue of *Data Communications LAN Strategies*, beginning on p. 24. Starting on p. 55 in the same issue, Randy Presuhn compares the common management information protocol (CMIP) to SNMP in "Considering CMIP."

For a tutorial on the switched multimegabit data service (SMDS) standard, in-

cluding its relationship to T1 and T3, see "SMDS: The Beginning of WAN Superhighways" by Tracy Cox et al. in the April 1991 issue of *Data Communications*, beginning on p. 105.

For interconnection of LANs, also see Chapter 10 of *Telecommunications: Protocols and Design*, by John D. Spragins et al., Addison-Wesley, Reading, Mass., 1991.

B-ISDN and how it works

In his article "Broadband Networks: The End of Distance?" in *Data Communications* (June 1990, p. 76), John M. McQuillan discusses how the new high-speed networks will transform the way information is processed. He also covers the relationships among fast packet switching, frame relay, cell relay, SMDS, fiber-distributed data interface (FDDI), and synchronous optical network (Sonet).

Seminars and workshops focusing on advanced applications for high-speed networks will be given at the 1992 IEEE International Workshop on Advanced Communications and Applications for High Speed Networks (March 16–19, Munich). For further information, contact Alfred C. Weaver, Department of Computer Science, Thornton Hall, University of Virginia, Charlottesville, Va. 22901; 804-982-2201; e-Mail Weaver at Virginia.EDU.

In-depth coverage of most aspects of gigabit networks was presented at the symposium on gigabit networks held in Washington, D.C., on July 15–17, 1991. For summaries of the presentations, call the program chairman, Albert Vezza, Laboratory for Computer Science, Massachusetts Institute of Technology, Cambridge, Mass.; 617-253-5852.

For background information, see "Broadband ISDN and Asynchronous Transfer Mode (ATM)" by Steven E. Minzer in IEEE *Communications Magazine*, September 1989, Vol. 27, no. 9, pp. 17–24. ◆

Acknowledgments

In preparing this special focus report on data communications, *IEEE Spectrum* called on many experts. We are especially indebted to the following individuals for their advice and guidance. Their identification with the report should not be construed as their endorsement of any of the opinions or products covered in these pages, nor of the accuracy of the statements made in the articles.

The advisers for this report were Richard Binder, principal scientist, Corporation for National Research Initiatives, Reston, Va.; Robert P. Davidson, manager for data networks, General DataComm Inc., Middlebury, Conn.; Jeremiah Hayes, professor, Concordia University, Montreal; Dipankar Raychaudhuri, head, Broadband Communications Research, David Sarnoff Research Center, Princeton, N.J.; and Stephen B. Weinstein, manager, Systems Integration Research Division, Bell Communications Research, Morristown, N.J.

Index

EDITORIAL

To obtain further information about the following companies, use the Reader Service Card facing p. 34 and circle the number matching the company.

HIGH-SPEED LANs

INTERCONNECTION OF LANs

B-ISDN SWITCHES

SONET INTEGRATED CIRCUITS

ADVERTISERS

Other agencies

(Continued from p. 20)

Speaking before a briefing to the IEEE-United States Activities (IEEE-USA) at the National Press Club in Washington, D.C., in July 1990, Green added: "The problem is not [President Bush's] ability to inspire, but rather that a manned Moon/Mars mission is not the right idea now."

Others are concerned by the possible domination of one major program over others. The future civil space program should consist of "a balanced set of five principal elements"—of which the human exploration of Mars preceded by a space station and an exploration base on the moon is only one, concluded the report of the Advisory Committee on the Future of the U.S. Space Program, chaired by Norman R. Augustine, chairman of Martin Marietta Corp., Bethesda, Md.

Reporting to NASA Administrator Richard Truly in December 1990, the Augustine committee said the other four elements should be a strong space science program, a mission to planet earth focusing on environmental measurements, expanded development of technology, and a robust space transportation system.

Furthermore, the committee states, "...any program with the ultimate, long-term objective of human exploration of Mars should be tailored to the availability of funding—and not to some fixed date for accomplishment."

ENGINEERS OPPOSE STATION. The Augustine committee is not alone in its views. On June 7, the IEEE-USA Technology Policy Council issued a statement calling on the U.S. Senate to oppose the full funding for the space station and, instead, support a scaled-back version costing less than US $10 billion for biomedical and psychological research into the effects on human beings of prolonged exposure to microgravity.

"A larger expenditure would seriously detract from other important civilian space programs, such as communications and remote sensing," the IEEE-USA council group reported.

The reinstatement of the space station funding was predicated on the delay of at least two unmanned space science projects. One is a large X-ray telescope that was scheduled to be launched in the late 1990s, and the other is a probe that will visit an asteroid on its way to a comet.

It has also come head to head with the proposed Earth Observing System (EOS), a proposed multidisciplinary and international effort to understand and monitor for the first time all of the earth's environmental systems. EOS is projected to be almost as expensive as the space station: some $30 billion over its 15-year life cycle. "[The] space station, coupled with EOS, cannot be fit into the shrinking discretionary domestic budget," said the House subcommittee chairman, Representative Robert Traxler (D-Mich.).

"I really believe we're seeing the final end of the Apollo era," said John Logsdon, director of the Space Policy Institute at George Washington University in Washington, D.C. "The space shuttle and the space station were attempts by NASA to re-create Apollo without recognizing the changed environment.

"The program needs to be reconstructed [in a form] appropriate to the 1990s and beyond—and one that I think is not appropriate is Apollo." In support of his position, Logsdon pointed out that the Augustine committee report calls for "reducing expectations to the level of priority society is willing to accept."

Those who compare Bush's Space Exploration Iniative with the Kennedy moon race, however, "have missed the whole point," asserted Lieutenant General (Retired) James A. Abrahamson, former NASA Associate Administrator for Space Flight, 1979–81. He feels the main thrust of Bush's 1989 speech was expressed in the objective "to live and work in space."

In Abrahamson's interpretation, the space station, returning to the moon, and going on to Mars are "milestones of a space infrastructure that will play an increasingly important role for all of us on earth in the next century."

Agencies and their missions in the U.S. space program

Agency	Initial budget for space, millions of US dollars (year)	1990 budget for space, millions of US dollars	Space activities and missions
Department of Defense	489.5 (1959)	19 382	Develops the National Launch System heavy lift booster jointly with the National Aeronautics and Space Administration (NASA); researches and develops the Strategic Defense Initiative (SDI); and operates the Defense Satellite Commmunications System (DSCS) and the Defense Meteorological Satellite Program (DMSP)
National Aeronautics and Space Administration	261 (1959)	11 393	Researches, develops, and operates technology for the space shuttle, space station, interplanetary probes and orbiting astronomical observatories, space and earth sciences and their applications, and manned and unmanned space exploration; encourages commercial space programs, technology transfer to universities and industries
Department of Commerce	50.7 (1962)	243	Oversees both polar-orbiting and geostationary operational weather satellites; administers the land remote-sensing program (which is conducted by Earth Observation Satellite Co., Lanham, Md.); and helps develop telecommunications policy for the use of geostationary orbits
Department of Energy	34.3 (1959)	190.3	Develops nuclear electric power reactors for U.S. earth-orbiting and interplanetary spacecraft, and provides instrumentation for space-based monitoring of nuclear weapons test ban
Department of Agriculture	0.5 (1968)	23.4	Conducts applications research on space-based systems for monitoring, assessing, and managing agricultural and forest resources, and impact analysis on droughts and floods
Department of the Interior	0.2 (1968)	15.5	Maintains remote-sensing resource data archive; uses remote-sensing data to inventory, monitor, and manage natural resources; assists various countries in remote sensing and geographic information systems; and has helped develop interplanetary spacecraft sensors and produced maps of planets and satellites
Department of Transportation	0.5 (1987)	3.5	Through the Office of Commercial Space Transportation, oversees and coordinates the U.S. commercial space transportation industry by issuing launch licenses, establishing insurance requirements, and researching policy issues
Arms Control and Disarmament Agency	—	—	Represents the United States in arms control negotiations, including those of space weapons systems
Department of State	—	—	Advises the President on international space matters, is responsible for evaluating and advancing U.S. foreign policy interests in the context of space activity, and represents the United States in international negotiations concerning space issues
Environmental Protection Agency	—	—	Conducts research and technical support using satellite remote sensing as part of an overall environmental monitoring program
National Science Foundation	—	—	Supports academic research in atmospheric sciences and ground-based astronomy
Smithsonian Institution	—	—	Conducts basic research and public education on astronomy and space-related topics
U.S. Information Agency	—	—	Disseminates information about U.S. achievements in space to other countries

Source: *Aeronautics and Space Report of the President: 1988 Activities*, NASA, 1990

The anatomy of NASA

NASA's internal technical and management troubles can be fixed—but some of the solutions being proposed are radical

Internal issues within the National Aeronautical and Space Administration that, until recently, had been widely discussed but largely consigned to the realm of anecdote have been brought out by several recent reports. Notable among those issues were the decline of NASA's in-house technical expertise, institutional aging, intercenter rivalry, and the balance between risk and excellence.

LESS TECHNICAL. "There is widespread agreement within NASA that the agency has lost too much of its in-house technical capability, that its employees do not have the opportunity to do as much 'hands on' work as they want, that NASA still turns over too much of its basic engineering and science work to contractors," concluded Howard E. McCurdy, professor at the School of Public Affairs at American University in Washington, D.C.

'NASA's in-house technical capability is eroding and needs rebuilding'

In an analysis published in the November 1989 issue of *Space Policy,* McCurdy pointed out that during the Apollo era "the desire of the NASA technical cadre to maintain its own capability reinforced faith in the importance of a 'hands on' organization, one in which government scientists and engineers laboured at workbenches rather than behind desks." In that environment, "funding, procurement regulations, paperwork and central clearance were secondary to problem solving." In spite of the huge expansion in contracting for engineering and manufacturing for Apollo, during the 1960s NASA officials treated service contracts as "occasional departures from the general norm that government provide such services in-house," McCurdy observed.

With the first deep post-Apollo funding cutbacks, however, contracting out was turned more into a way of life. Contract employees were even put in charge of all major space shuttle launch operations.

In a 1988 survey McCurdy distributed to a random sample of 800 NASA professional employees, "fewer than 4% of the professional workforce reported that they spent most of their work week 'working in a laboratory, test facility, control or tracking center, training astronauts, or working on space flight or aeronautics hardware.' " Meanwhile, 76 percent responded that they "spent most of their work week like other government bureaucrats, 'working at a desk in an office.' " In short, "The NASA of the 1980s became as a result a very different organization from the NASA of the 1960s—much older, more bureaucratic, with much less in-house technical capability."

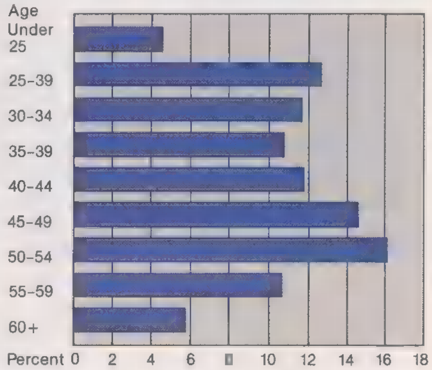
NUMBERS CONFIRM. McCurdy's results were corroborated by a two-volume study titled *Maintaining the Program Balance*, conducted by the National Academy of Public Administration in Washington, D.C., for NASA Administrator Admiral Richard Truly. Published in January, it summarized the results of a survey of 72 current and former senior NASA managers and 1567 upper-level NASA scientists and engineers on the distribution of science and engineering work between NASA and its contractors.

"The panel concludes that NASA's in-house technical capability is eroding and is in need of rebuilding," the report stated—a conclusion with which the surveyed NASA and contractor managers agree "by a ratio of four to one." The NAPA study confirmed that an increasing number of engineers and scientists are monitoring contracts instead of working with hardware.

Part of the evidence for that is in the numbers: while NASA's in-house population of scientists and engineers has remained between 11 500 and 13 000 since 1972, between 1987 and 1990 the population of contractor scientists and engineers has doubled from about 6500 to 13 000. In fiscal 1989, contracting consumed 88 percent of the NASA budget, or more than US $10 billion.

The evidence is also in the sentiment of NASA personnel. The NAPA study quoted one engineer as saying that NASA engineers are not as sensitive to hardware as they should be because "they are absorbed in program status presentations and don't get any hands-on experience beyond the utilization of copying machines." Another engineer was quoted as saying: "Once engineers become contract monitors, not doers, the appeal of their jobs fade[s], unless opportunities for real direction are part of the monitoring effort."

Age profile of NASA's permanent employees



Source: National Aeronautics and Space Administration

Bimodal (two-peaked) age distribution of permanent employees of NASA shows that over the past decade, the distribution of age and experience at NASA has moved from a maximum share within the 35–50 age bracket—from which NASA draws its senior managers—to maxima at 25–29 and 45–59 years. Based on historical attrition rates, NASA will lose half its senior managers this decade.

The diminishing of in-house technical capability also caused the NAPA panel to conclude that "NASA may be losing its ability to operate as a smart buyer of technical products and services, and to control and oversee that work in all technical respects." Moreover, many scientific and engineering activities within NASA have been shifted from core R&D into "project management, flight program and research facility operations, and the fields of reliability, quality, and safety"—a shift that the panel believes is "detrimental to the core science and engineering capabilities of the development centers." The panel recommended that as many technical projects as possible be brought back inside NASA.

PAY AND RESTRICTIONS. Both the 1990 Augustine committee on the future of the space program and the NAPA panel expressed concern over NASA's ability to attract experienced technical personnel because of the disparity in salaries between employees in civil service and those in industry. A 1989

study of the Bureau of Labor Statistics indicated that Federal employees averaged 28.6 percent below those of the private sector.

The Augustine committee cited an unpublished NASA study of compensation, which showed that the director of one of the NASA field centers was paid about half as much as a person with equivalent responsibilities in industry. Even starting salaries for college graduates in NASA are US $5000–$10 000 lower than those in industry, especially in high-cost-of-living areas—a problem particularly acute in science and engineering disciplines.

A second problem are recent conflict-of-

Present and future technologies required for the Space Exploration Initiative

Functional requirement	System characteristics	System options
Propulsion		
Surface to low earth orbit	High thrust, 150–250-metric-ton capacity	Advanced chemical-fuel rockets (cryogenic liquids, noncryogenic liquids, solids)
Transfer orbit to the moon and Mars	Restartable motors; stable, storable propellants; for Mars, very high specific impulse	For the moon, current propellants and systems; for Mars, nuclear thermal rockets, nuclear electric propulsion
Insertion into planetary orbit and descent to surface	Throttleable; high reliability required; long-term cryogenic storage	Not demonstrated by present systems
Electric power		
Moon mission spacecraft	Manned: up to 30 kW for week(s); unmanned cargo: up to 5 kW for week(s)	Nuclear: presently 7 W/kg with radioactive thermoelectric generators
Mars mission spacecraft	Manned: up to 20 kW for year(s); unmanned cargo: up to 5 kW for year(s)	Fuel cells: presently 250 Wh/kg Batteries: presently 20 Wh/kg
Moon and Mars mission surface activities	Habitat/laboratory: 30–100 kW; base: 100–1000 kW; rovers: 100–4800 kWh per trip All systems reliability must be greater than 99 percent, with minimal support for continuous operation	Photovoltaic: presently 21 Wh/kg at earth Photovoltaic with storage batteries: presently 3 W/kg Photovoltaic with fuel cells: presently 0.7 W/kg on the moon; will need to be 3 W/kg on Mars Direct power transmission: no practical system available
Extravehicular activities		
Space suit	Suit gloves must be reliable, mobile, flexible, comfortable, easily maintainable; their design affects suit's internal pressure, breathing gas mixture	Current suit designs not adequate for long stays on the moon or Mars
Life support systems		
Waste management	Technology largely driven by closure of food cycle (recycling human and plant waste)	Key research areas: plant growth techniques, food production, waste processing, contaminant control, and systems integration and control
Water recovery	Organic and inorganic waste removal from multiple sources; must provide drinkable water	Distillation systems, thermoelectric integrated membrane evaporation, vapor compression, bioregenerative (plant-growth–based) systems
Air revitalization	Carbon dioxide reduction and removal; oxygen generation; trace-contaminant control	Molecular sieve, chemical reactors (Bosch or Sabatier), direct carbon dioxide electrolysis
Planetary surface systems		
Habitats	Moon: six persons for week(s) to 18 for year(s); Mars: six for month(s) to 18 for year(s) Radiation protection, simple maintenance essential	Inflatable and rigid structures
Rovers and walkers	25–100-km radius for several-day missions	Sensors, software
Robots	Teleoperated; require data rates over 500 megabits per second, resolution 30 arcseconds at center; user-friendly, dependable, and rugged	Very high-definition stereo television (10 000-line TV)
Site characterization		
Stereo visual imaging	Local maps with 1-meter resolution; global maps with 10–100-meter resolution	Achieved with present technology
Resource characterization	Multispectral imaging, chemical, and evolved gas analyses	Spectrometers, electromagnetic sounders, gas chromatography, surface penetrators
Spacecraft		
Low-earth-orbit personnel shuttle and heavy lifter	Spacecraft designs limited by materials properties and fabrication methods	Current spacecraft designs based on aluminum and titanium
Moon and Mars transfer vehicles, cargo transfer vehicles, landers	Minimal on-orbit assembly, maximum crew safety, radiation protection	Light alloys, metals, ceramics, polymer matrix composites need development; radiation shielding possibilities include water, magnetic, and electrostatic
Communications, control, navigation		
Mission control, science data return, radiometric support for navigation	Moon: downlink 350 Mb/s, uplink 250 Mb/s Mars: downlink 20 Mb/s; uplink 10 Mb/s Navigation: 10 meters accuracy Driven by imagery data rates	Present interplanetary navigation systems cannot adequately support real-time Mars navigational requirements; options include optical bands, phased-array antennas, multibeam antennas, millimeter-wave integrated circuitry, expert systems, neural networks, data compression techniques

Source: *America at the Threshold*, Report of the Synthesis Group on America's Space Exploration Initiative, May 1991

interest restrictions on the type of work Federal employees may accept after leaving Government service. The Augustine committee noted cases where in part because of the restrictions, individuals refused to consider an executive-level position at NASA and a number of other "extraordinarily talented NASA employees have elected to terminate their government service."

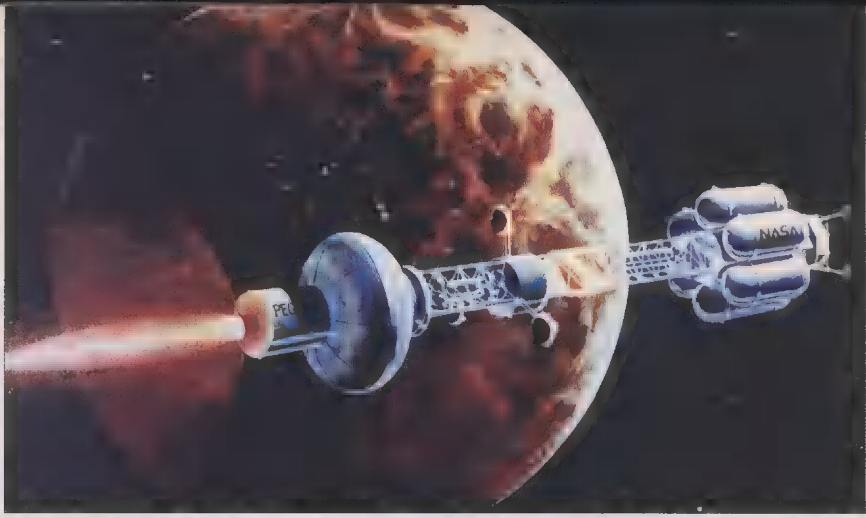
"Even more acute problems for NASA" are presented by "[t]he difficulty of removing civil servants who are not performing up-to-standard work," the report said, limiting the agency's "ability to recruit new talent to meet future challenges."

The Augustine committee also noted a "bimodal" age distribution of NASA employees —that a disproportionate number are either within 10 years of retirement or are relatively newly hired, leaving a dip in "the pool of talent in the 35–49 year bracket, from which future senior managers are usually drawn" [see figure, p. 46].

POLITICS PREVAILS. Further, the Augustine report directly noted the resistance of the various NASA centers to supporting one another or to taking direction from headquarters in Washington, D.C.—a reluctance that also concerned the Rogers Commission investigating the Challenger accident. Although NASA managers have been trying "to redress these long-building trends," the Augustine report said, "much remains to be accomplished in this most difficult of management challenges, a cultural shift."

The NAPA study also noted that a number of NASA employees were concerned that the agency is "increasingly driven by the motivations, interests, and strategies of managers, industry representatives, and politicians who dominate decisions" rather than by the interests and demands of the scientific and engineering communities and the public. "Most prominent among opinions" of those surveyed "was the belief that selling of programs" to politicians "has led to competition among centers to enlarge their own budgets and loyalty to particular centers rather than to NASA as a whole," wrote the NAPA panel.

"The centers are competitive in that they're all chasing the same set of dollars. So they tend to be somewhat parochial and secretive and cooperation is difficult," explained former NASA Administrator James Beggs. "The same thing exists in large American corporations between divisions. They don't want to accept what another center has made, or work closely together, so they duplicate effort."



Department of Energy

Artist's conceptual painting of a manned spacecraft drifting toward Mars shows one possible design incorporating a nuclear electric power generating system under development by General Electric Co. under contract to the U.S. Department of Energy (DOE). The 100-kW system, called the SP-100 reactor, converts heat generated within a compact high-temperature nuclear reactor directly into electricity through the use of thermoelectric cells.

In Beggs's view, the cure is "a strong centralized management organization to bind them together, to make sure things fit"—which Brigadier General Samuel Phillips, Apollo program manager in the 1960s, did from NASA headquarters in coordinating the mission to the moon. But, Beggs said, "it's very hard to create that today. Congress is jealous of maintaining manpower control, and won't let the agency expand in Washington, D.C."

Others disagree. "I think the issue of intercenter rivalry is overstated," said former NASA Associate Administrator James A. Abrahamson. "Every center is capable, but has its own mission." In his view, the more pressing problem is the new laws restricting the salaries of civil service employees.

PERSPECTIVE ON TROUBLES. "Our [technical] failures are coming not from unknowns, but from knowns," said veteran space journalist Alcestis Oberg in Dickinson, Texas. She pointed to the misshaping of the Hubble Space Telescope mirror after many large mirrors of the same design had been figured for ground-based telescopes. With the stand-down of all space flight for 2-1/2 years after the Challenger accident, NASA "had years to look at it." Moreover, she added, errors in manned space flight are particularly serious: "there is death waiting out there. There is no excuse for poor quality control."

"We are not perfect, but considering the scientific and technical realm within which we operate and the ever attendant inherent risks, we do very well by most standards of success," observed NASA Assistant Deputy Administrator John E. O'Brien.

The Augustine committee pointed out that "even with an objective of perfection, such challenging undertakings entail risk." But it expressed concern that "as a nation, we are becoming risk averse." "Success should be sought, and prized when achieved, but not always expected," the committee wrote. "If it is expected, people will stop taking chances, and... nothing great will be accomplished."

'PLUS ÇA CHANGE...'

Historically, Bush's 1989 Space Exploration Initiative to the moon and Mars did not create a new program so much as get the country back on track of a long-standing one, first laid out by NASA's Office of Program Planning and Evaluation in *The Long Range Plan of the National Aeronautics and Space Administration*, Dec. 16, 1959: "...[T]he manned space flight program, the space vehicle development program and the program of unmanned lunar and planetary exploration are all oriented toward the ultimate objective of manned flight to the moon and the nearby planets."

That goal was affirmed in September 1969 by Vice President Spiro T. Agnew's Space Task Group Report to the President, *The Post-Apollo Space Program: Directions for the Future*: "As a focus for the development of new capability, *we recommend* the United States accept the long-range option or goal of manned planetary exploration with a manned Mars mission before the end of this century..."

In March 1986 that aim was reaffirmed by Thomas O. Paine's National Commission on Space, whose report *Pioneering the Space Frontier* said "...the Commission recommends a new direction for our civilian space program that we believe will advance the broader goals of 21st-century America: To lead the exploration of the space frontier...[to] support human settlements beyond Earth orbit, from the highlands of the Moon to the plains of Mars."

All but the 1959 plan called for a permanent space station in low earth orbit to examine the effect of long-duration weightlessness on living organisms, a space shuttle to ferry people and supplies from the earth to the space station and back, and permanent colonies on the moon both to mine local resources for earth and to test out vehicles and other systems for use on Mars.

In fact, President John F. Kennedy's 1961 call to go directly to the moon was the aberration in short-cutting past the original plans for a space station. And the space shuttle seemed to have no purpose for years because in the early 1970s, when a Mars mission was politically unacceptable, the shuttle was cut free from the goal of serving a space station.

"There's always been a long-range plan," remarked Jerry Grey, director of science and technology policy for the American Institute of Aeronautics and Astronautics, headquartered in Washington, D.C. "There just hasn't always been a commitment to it." —*T.E.B. and K.E.*

The international context

Advice to the United States from overseas: know what you want, commit to the end, and don't strand global partners

"Is NASA still the world leader? Yes. The undisputed leader? No," declared former National Aeronautics and Space Administration (NASA) Associate Administrator James A. Abrahamson. "NASA is still premier as a generator of technology and vision. But its position in world space activities is being challenged in some areas. Further, our national leadership is also dependent on the capability of American industry, which is also under attack," said Abrahamson, who is now executive vice president for corporate development at Hughes Aircraft Co., Los Angeles.

The European Space Agency (ESA) is almost as old as NASA, if its origin is dated back not to its 1975 incorporation but to the 1964 birth of its predecessor organizations, the European Space Research Organization (ESRO) and the European Launcher Development Organization (ELDO).

The ESA of today is less than 10 percent the size of NASA, with 1900 employees compared with 24 000. It does limited in-house engineering, the majority of such hardware work being carried out under contract in European industry except for acceptance testing of satellites, batteries, and components.

Japan's space agencies are even older. Since the 1950s, the Ministry of Education's Institute of Space and Astronautical Science (ISAS)—the arm of Japan's space program responsible for space science and exploration—has developed small scientific satellites.

Since 1969, the National Space Development Agency (Nasda), which oversees space applications, has developed and operated launch vehicles for communication, broadcasting, meteorological, and earth-resources observation satellites. The Japanese space agency is now training astronauts for manned space flight and has flown a journalist aboard the Soviet space station Mir.

"It's more efficient to operate on a multiyear appropriation"—that is the big lesson the European and Japanese experience holds for NASA, at least according to Ian Pryke, head of ESA's Washington, D.C., office.

LESSONS FROM ABROAD. For example, in 1987 the ESA Council agreed that the new Ariane 5 launch vehicle should take eight years to develop. So the council committed to the full eight-year appropriation, Pryke said, calculating up front the complete cost for finishing and testing through the pre-operational phase. The first launch of the Ariane 5 is expected in 1995.

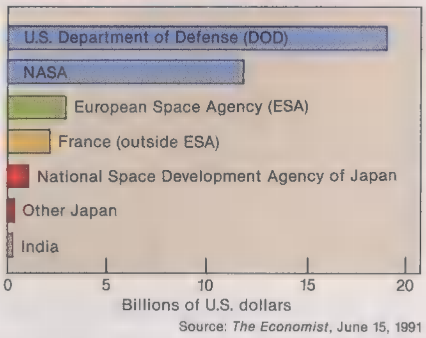
In addition, ESA allows a modest cost overrun, which for the Ariane 5 is 20 percent over the projected cost. If run-out costs exceed this ceiling, then the nations through ESA can decide whether to raise the ceiling, lower the program's sights, or end the program, Pryke said.

But in the United States, with its annual appropriations process, Pryke pointed out "the horizon is never longer than a year. And you continually have to revisit what you're doing—that is a costly waste of manpower."

Multiyear funding is not a new concept in the United States. In its 1986 report to then-U.S. President Ronald Reagan, the National Commission on Space chaired by Thomas O. Paine recommended "Multi-year procurements to replace year-by-year funding with firm decisions that eliminate annual changes..." The Augustine committee on the U.S. space program's future also proposed multiyear funding in its report last December.

According to NASA's Assistant Deputy Administrator John E. O'Brien, the space agency itself is in agreement "that multiyear political and fiscal underpinnings for space programs is essential in order to assure basic stability and enable prudent planning."

Space budgets, 1990



In 1990, the U.S. Department of Defense's budget for space technology and operations was significantly larger than the budget of the National Aeronautics and Space Administration, and both are still the largest in the world.

The United States may be moving in that direction, even if it is with glacial speed. For example, the Endeavour—the replacement orbiter for the Challenger—was budgeted at US $2.1 billion, which was given to NASA in a lump sum in 1987 for completion this year. It came through on schedule and $300 million below budget.

HONOR THY NEIGHBOR. A multiyear commitment guarantees continuity for international partners as well. A low point in ESA-NASA cooperation was reached in 1981, ESA's Pryke observed, when NASA abruptly terminated its spacecraft in the International Solar-Polar Mission, a joint program with ESA to study the sun.

NASA and ESA each were supposed to build identical spacecraft that would be launched together out toward Jupiter; in a gravitational slingshot maneuver around the large planet, the two spacecraft would be flung back around the sun, one over the north pole and one over the south pole, to study both spatial and temporal differences in the solar wind and magnetic fields. But in a budget battle, NASA unilaterally deleted its spacecraft. (ESA's single craft, renamed Ulysses, was launched last year by NASA as part of a continuing cooperative program.)

Similarly, during a 1989 budget battle, NASA started revising the space station unilaterally, upsetting all the non-U.S. partners, Pryke said. But the House subcommittee's cancellation in May of the funds for the space station stirred up the international partners to the point of sending blunt threats.

Japan, through Nasda, was to supply a $2 billion space laboratory to be attached to the station for use of all the international partners, and had already spent some $300 million on developing the Japan Experiment Module. So in May the Japanese Government warned the United States that if the space station were killed, Japan could pull its promised billions of dollars out of other multinational U.S.-led megaprojects, such as the jointly sponsored superconducting supercollider.

The importance of maintaining pledged faith with its international partners is fully realized within NASA. "I wholeheartedly agree that the United States should honor its international agreements for space pro-

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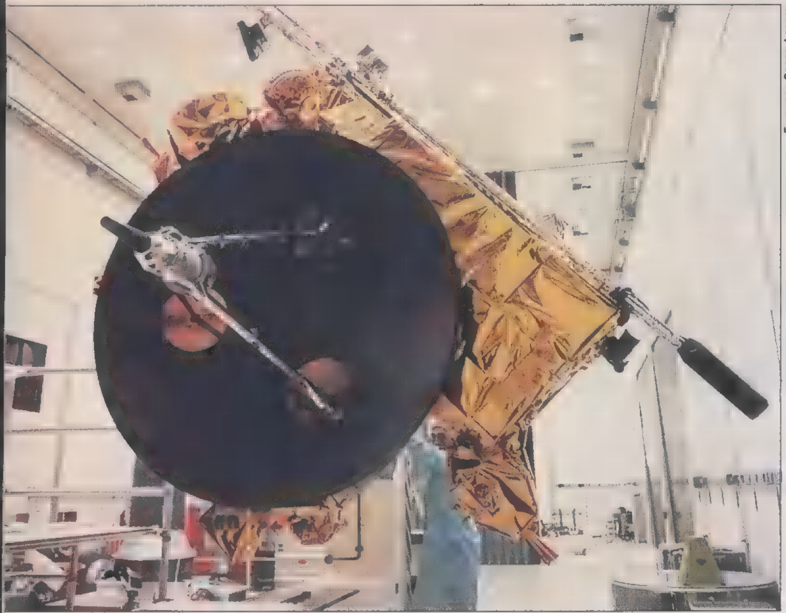
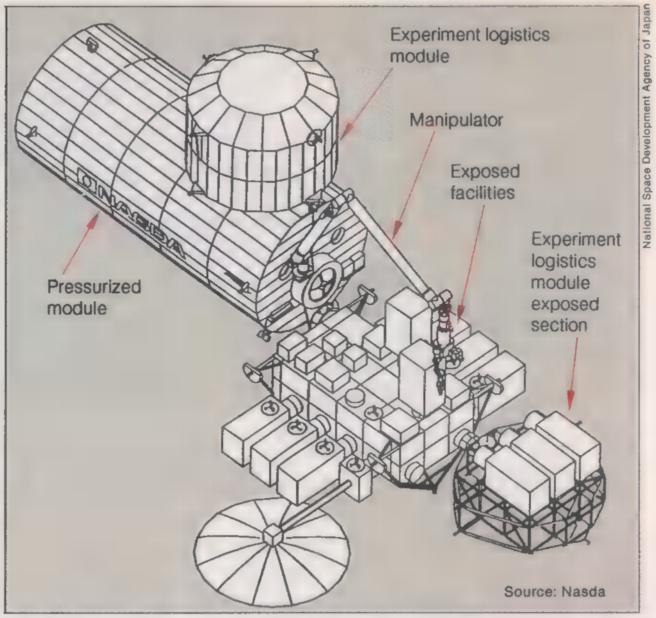


The Ulysses spacecraft, built by the European Space Agency (ESA), is tested at the European Space Technology Center (ESTEC) in the Netherlands before being launched by NASA last year. Ulysses was originally one of two identical spacecraft, one of which was to be built by ESA and the other by NASA, to be launched into polar orbit around the sun. In 1981, NASA eliminated the funding for its spacecraft.*



The Japanese Experiment Module, to be built by the National Space Development Agency of Japan (Nasda), is designed to attach to the U.S. Space Station Freedom. According to Nasda's agreement with NASA, every country that intends to use the space station for scientific or engineering research will also be able to install its experiment equipment into standard racks inside the module.

gram such as the Space Station Freedom,'' said NASA's Assistant Deputy Administrator O'Brien.

KNOW GOALS. ''Is there a European rationale for going to the moon? What can we do on the moon that we can't do on the earth?'' asked Pryke. ''We won't do it just because the United States is doing it,'' he said. Only when those questions are answered will ESA feel equipped to negotiate a cooperative program, he said.

Such a goal-oriented approach is somewhat different from the official U.S. approach. ''NASA's advanced planning is more focused on missions than on discovering and demonstrating new economic benefits for the Earth,'' observed David Criswell, director of the University of Houston's Institute of Space Systems Operations in Texas.

To change that emphasis, Vice President Quayle's Synthesis Group ''tried to focus on overriding reasons for going into space instead of focusing on things like the shuttle and space station,'' said the group's technical evaluator Stewart Nozette. In assessing alternative approaches for implementing Bush's Space Exploration Initiative, the Synthesis Group tried to ''come up with fundamental objectives'' for going to the moon or Mars, said Nozette.

Some of those objectives, outlined in the group's report in June, include discovering new sources of energy, searching for earthlike planets around other stars, and determining whether life ever existed on Mars. Only then did the Synthesis Group work backwards to examine what kinds of technologies would be needed in order to accomplish those goals, Nozette said.

Knowing goals also means setting top priorities. But NASA has often been forced to dip into the reserve funds for scientific research projects to help finance space shuttle cost overruns, and the tendency seems to be carrying over to the space station, as indicated by the House's reinstatement of funding.

R&D VERSUS OPERATIONS. This behavior has reawakened old questions about whether NASA should further separate scientific research and development from daily operations.

> 'Why would Europe want to go to the moon?'

In Europe, ESA pursues R&D through the preoperational design and development of launch vehicles and satellites. When a program has come of age operationally, it has been handed off to an independent organization, which has sometimes been set up for the task. Examples are Arianespace for launches, Eumetsat for the operation of meteorological satellites, Eutelsat for the operation of telecommunications satellites, and SPOT Image Corp. for the operation of land remote-sensing satellites. ESA's program for building maritime communications satellites also contributed two of them to the first-generation space segment of the International Maritime Satellite Organisation (Inmarsat).

The United States has separated operations from R&D to a degree. Communications satellites were spun out of NASA to Comsat Corp., Washington, D.C., in 1965, meteorological satellites to the National Oceanic and Atmospheric Administration in 1984, land remote-sensing satellites to the quasi-commercial organization Earth Observation Satellite Co. (Eosat), Lanham, Md., in 1984.

Moreover, the operation of the Delta, Atlas, and Titan expendable launch vehicles has been turned over to the companies that originally built them (respectively, McDonnell Douglas Astronautics Co., General Dynamics Corp., and Martin Marietta Corp.)

For at least a decade various interests have urged that the shuttle be managed by a separate agency. Some have contended that the present arrangement begs the question whether NASA is a research agency or an airline operating to a schedule. Others maintain that the shuttles, in spite of airline-like publicity in the 1970s, are still complex R&D vehicles.

Most recently, the Augustine committee endorsed a 1988 recommendation by the National Academy of Public Administration, that NASA set up within itself an Associate Administrator for Space Flight Operations, to manage the space shuttle, certain expendable launch vehicles, and tracking and data functions on the ground. Whether or not such an appointment will be made is still to be determined.

The future considered

To remain competitive in space, the U.S. government must heed lessons from other countries and its own past—and set basic priorities

In the debate over the direction of the U.S. space program, some fundamental issues must be resolved if the United States is to remain competitive for the 1990s and beyond.

Many experts, including the Augustine committee, feel that, for the U.S. space program to be viable over the long term, one major priority has to be meeting the nation's most urgent, long-term needs: energy, international competitiveness, employment, education, and environmental monitoring. Specific missions should be structured to meet specific needs.

Indeed, some feel that the House Appropriations subcommittee's killing of the $2 billion for the space station was pitting space research against social programs, observed Marc Bensimon, NASA's deputy manager of the Space Station Freedom program and operations in Reston, Va.

On the contrary, space activities can offer "new ways to meet old needs" such as "providing new sources of cheap, clean electric power," said the University of Houston's David Criswell. To explore technical options, in May the Department of Energy sponsored a meeting on power from space.

HOW MUCH IS RIGHT? The Federal government then needs to decide how much those goals are worth.

One possibility is the "go as you pay" setup suggested in the Augustine report, whereby the nation decides each year how much money it can afford for space, and sets the size of the program and its date for completion accordingly. Another is level-of-effort funding, in which annually the Administration requests a relatively constant budget for NASA. "Space science has been operating on what amounts to a level-of-effort basis for many years," said AIAA's Jerry Grey.

Regardless of the funding scheme, most sources agree that in the 1990s, a single-goal Apollo-style initiative is no longer appropriate nor is even possible, because there are a great many important space activities.

In addition, NASA must be honest up front with funding estimates. So far, NASA's tendency to underbid the initial cost—repeated since the early 1970s with the building of the space shuttle—has worked "because we keep giving them money," said George Washington University's John Logsdon. "They've not been penalized, so why change it?" The House Appropriations subcommittee's removal of the funds for the space station may signal, for the first time, Congress's hesitation that such a large project may be even costlier than expected.

STOP POLITICAL GAMES. Many sources feel both the Federal government and NASA should consider changing certain political practices if the nation is to be best served.

One is to minimize the effects of political patronage—often called "pork-barrel politics"—in which regional politics influence technical decisions.

"The best way to fix the space station design today would be to start over," said Grey. "But you'd end up with pretty much the same design as before, because the [political] environment in which the space station originated is still with us. It would still have to be built in five places because those are the districts of five Congressmen and Senators." He added: "NASA did exactly what it was told to do: to make the space station all things to all people, otherwise it wouldn't get the money." The only way out is to "change the political environment," he said.

COMMIT TO THE END. One significant change would be to commit to each space project over many years to completion.

"The parliamentary system tends to be a little better than a division-of-power system, such as we have, because the executive comes out of the Parliament and so it is the legislature," said former NASA Administrator James Beggs. "But basically they just decide to do it. And we could decide to do it. The argument used against it is Congress doesn't think they can commit future Congresses to a course of action. In truth, they just don't want to do it."

Advice from other nations to the U.S. space program is: don't alienate international partners—because on them rests the future of other large projects.

REGAIN HIGH TECH. Since NASA is the lead agency in the multiagency U.S. space program, its technical culture must be "beefed up," said Beggs. That means attracting new engineers out of college "because new ideas come from young minds," he said.

Fostering NASA's technical capabilities may require repealing the ethics rules adopted in the 1980s, which hinder people in industry from moving to NASA and back again, as used to be common, and changing civil service regulations so that the best people could be paid the same as in industry.

In addition, some fundamental lessons learned by the non-U.S. space agencies have to be relearned by NASA. For example, "We taught the Japanese how to do statistical quality control, and they beat our pants off because we forgot how," Beggs said.

Last, but far from least, "Developing science and technology are the foundation of national power, the wellspring of future economic activity," Beggs said. In the United States, the space program is a vital part of that. He added: "We could have a magnificent future if we don't lose faith." ◆

TO PROBE FURTHER

The Augustine committee presented its recommendations in *Report of the Advisory Committee On the Future of the U.S. Space Program*, U.S. Government Printing Office, Washington, D.C., December 1990.

John Logsdon analyzed the lack of overarching goals for the building of the space shuttle in "The Space Shuttle Decision: Technology and Political Choice," *Journal of Contemporary Business*, Vol. 7, no. 3, 1978, pages 13–29. He updated that analysis in "The Space Shuttle Program: A Policy Failure," published in *Science*, May 30, 1986.

David Criswell and R.D. Waldron have outlined how space could be used to meet the energy needs of earth in the 179-page *Report of NASA Lunar Energy Enterprise Case Study Task Force*, NASA Technical Memorandum 101652, July 1989.

For insights into psychology and perception, see two *IEEE Spectrum* articles by Trudy E. Bell and Karl Esch: "The fatal flaw in Flight 51-L," February 1987, pp. 36–51, and "The space shuttle: a case of subjective engineering," June 1989, pp. 42–46.

The loss of technical expertise within the space agency is documented by Howard E. McCurdy in "The decay of NASA's technical culture," *Space Policy*, Vol. 5, no. 4, November 1989, pp. 301–10. His conclusions are corroborated by the National Academy of Public Administration's two-volume study *Maintaining the Program Balance: A Report by an Academy Panel Examining the Distribution of NASA Scientific and Engineering Work Between NASA and Contractors and the Effect on NASA's In-House Technical Capability*, January, 1991.

IEEE Field Awards

Among the recipients this year are experts in performance modeling, optoelectronic devices, CMOS, and image sensors

The IEEE gives field awards annually to acknowledge outstanding contributions to electrical and electronics engineering. The IEEE's Board of Directors, after considering recommendations from the Awards Board, has chosen recipients for 18 field awards for 1991.

Generally presented to honor technical achievement in a particular IEEE field, the awards consist of certificates, honoraria worth up to US $2000, and, in some cases, bronze medals.

In the order of date presented—the first nine by May 13, the remainder from June through December—the 1991 awards go to the following 20 recipients:

- The Cledo Brunetti Award to Hideo Sunami (SM) "for contributions in the invention and development of the trench capacitor DRAM cell."
- The Herman Halperin Electric Transmission and Distribution Award to John G. Anderson (LF) "for contributions to the insulation coordination of electric power transmission lines."
- The Koji Kobayashi Computers and Communications Award to Stephen S. Lavenberg (F) and Martin Reiser (F) "for fundamental contributions to the theory and practice of computer and communications systems performance modeling."
- The Morris E. Leeds Award to David H. Auston (F) "for pioneering work on the generation and detection of ultrashort electrical pulses and their application to studies of optoelectronic materials and devices."
- The Frederik Philips Award to Gene Strull (F) "for outstanding accomplishment in the management of microelectronics and integrated circuit development and their applications to aerospace systems."
- The Emmanuel R. Piore Award to Joseph F. Traub (M) "for pioneering research on algorithms and computational complexity, parallelism, and optimal iteration theory, and for leadership in computing education."
- The Solid-State Circuits Award to Frank M. Wanlass "for the invention of Complementary MOS (CMOS) Logic Circuitry."
- The Charles Proteus Steinmetz Award to Fletcher J. Buckley (SM) "for contributions to IEEE Computer Software Standards Activities."
- The Nikola Tesla Award to Michel E. Poloujadoff (F) "for contributions to the theory of electrical machinery and its application to linear induction motors."
- The Control Systems Science and Engineering Award to Roger W. Brockett (F) "for pioneering and innovative contributions to nonlinear control, stability, robotics, and control engineering education."
- The Harry Diamond Memorial Award to Harold L. Hughes (M) "for contributions and leadership in the field of radiation hardening of microelectronic devices."
- The Masaru Ibuka Consumer Electronics Award to Gilbert F. Amelio (F) "for contributions to the development of charge-coupled device image sensors, leading to their near universal use in consumer video cameras."
- The Richard Harold Kaufmann Award to John R. Dunki-Jacobs (LF) "for contributions to the design and implementation of industrial power systems."
- The Morris N. Liebmann Memorial Award to Morton B. Panish (F) "for outstanding contributions to the epitaxial growth of compound semiconductor materials and devices."
- The Jack A. Morton Award to Tak H. Ning (F) and Hwa N. Yu (F) "for contributions to the development of advanced bipolar and MOS devices."
- The Judith A. Resnik Award to Leslie J. Deutsch (M) "for contributions to the theory and practice of deep-space telecommunications and information processing."
- The David Sarnoff Award to Federico Capasso (F) "for pioneering contributions to heterostructure devices through the use of bandgap engineering techniques."
- The IEEE Award in International Communication to Jack M. Sipress (F) "for technical leadership in developing the first transoceanic fiber optic cable system."

Hideo Sunami (SM), who received the Cledo Brunetti Award, is with the Semiconductor Design and Development Center of Hitachi Ltd., Tokyo. He joined Hitachi in 1969, became head of the company's integrated circuits research department in 1987, and moved to his present position in August 1990. He described his work with the trench capacitor at the 1982 International Electronic Devices Meeting. Since then the trench cell has been used in commercially available dynamic RAMs of 1M bit and up and it is expected to be increasingly important in the development of DRAMs storing 64M bits and beyond.

John G. Anderson (LF), who received the Herman Halperin Electric Transmission and Distribution Award, is a senior consultant with Power Technologies Inc., Schenectady, N.Y. He spent 38 years of his career in various capacities with General Electric Co., during which he served as technical director of Project EHV and manager of Project UHV. He has published papers on the mechanism of dielectric breakdown in oil-immersed structures and on the development of the Monte Carlo method of lightning analysis of transmission lines. He made major contributions to early research on the switching surge flashover performance of 500-kV and 765-kV transmission towers.

Stephen S. Lavenberg (F) and **Martin Reiser** (F), who received the Koji Kobayashi Computers and Communications Award, worked together at IBM Corp.'s Thomas J. Watson Research Center, Yorktown Heights, N.Y. There, in the late 1970s, they invented mean value analysis, which has strongly influenced both the theory and practice of computer and communication system performance modeling. Lavenberg is now senior manager of the systems analysis department at Yorktown Heights. Reiser is currently advising IBM on communication strategies while pursuing individual projects in cooperation with the Swiss Federal Institute of Technology in Zurich. He is the inventor of adaptive window protocols, which today are widely applied in local-area and wide-area networks.

David H. Auston (F), who received the Morris E. Leeds Award, is chairman of the department of electrical engineering at Columbia University, New York City. He had previously been on the technical staff of AT&T Bell Laboratories, Murray Hill, N.J., where he developed a new approach to the measurement of the high-speed properties of materials and devices, one that uses picosecond and femtosecond lasers to probe the electronic response of semiconductor materials, devices, and circuits. This measurement technique, known as ultrafast optoelectronics, permits the generation and measurement of electronic signals with a time resolution as fast as 250 femtoseconds.

Gene Strull (F), who received the Frederik Philips Award, is the vice president–technology and general manager of the Advanced Technology Division of Westinghouse Electronic Systems Group, Baltimore, Md. He is responsible for the development and manufacture of advanced electronic components and for various technology initiatives. Included are very large-scale integration circuits, infrared and visible sensors, monolithic microwave integrated circuits, and radiation-hardened electronic devices. He holds 21 U.S. patents, including one for the first molecular electronic device. He has published more than 50 papers.

Joseph F. Traub (M), who received the Emanuel R. Piore Award, is chairman of the computer science department at Columbia University, New York City. He began his research on computational complex-

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ity in 1959 while at AT&T Bell Laboratories. More recently his investigations have included the power and limitations of randomization and the implications of the intractability results of theoretical computer science for computational science. He is the author or editor of eight books and 100 journal articles and is the founding editor of the *Journal of Complexity*.

Frank M. Wanlass, who received the Solid-State Circuits Award, is chief scientist at Standard Microsystem Corp., Cupertino, Calif., where he is developing ultrahigh-speed CMOS circuits using silicide technology. While at Fairchild Semiconductor Research and Development in the early 1960s, he invented the concept of CMOS logic and constructed CMOS logic circuits out of discrete p- and n-MOS transistors. Wanlass discovered the main cause of MOS threshold instability to be sodium contamination and solved the problem with electron beam aluminum evaporation.

Fletcher J. Buckley (SM), who received the Charles Proteus Steinmetz Award, has been a software engineering manager since 1975 at RCA Corp. and after the takeover at General Electric Co. In 1976 he served on the original committee that founded the Software Engineering Standards Committee of the IEEE Computer Society and later became its chair. He was later chair of the IEEE P370 standards working group and the first Computer Society vice president for standards. As a member of the IEEE Standards Board, he was instrumental in initiating the thrust toward transnationalization of IEEE standards and produced the IEEE Standards Board publication, "A Guide to IEEE Standards Development."

Michel E. Poloujadoff (F), who received the Nikola Tesla Award, has been a professor at the Institut Polytechnique in Grenoble, France, for 25 years. He contributed to the analysis of induction machines, developed modern approaches to the modeling of squirrel cages, and defined the basis of the first entirely three-dimensional analysis of large transformers. In recent years, his efforts have focused on the practical application of Floquet's theorem, which is related to periodic coefficient differential equations such as electric machine equations, and on the theory of optimization of electrical machines.

Roger W. Brockett (F), who received the Control Systems Science and Engineering Award, is Gordon McKay Professor of Applied Mathematics, Harvard University, Cambridge, Mass. Since 1983 he has devoted most of his research to aspects of intelligent machines: robotics, computer vision, and real-time control. During this period, he has been instrumental in initiating efforts to expand the opportunities for undergraduate engineering at Harvard, including the development of teaching and research laboratories for robotics and engineering design.

Harold L. Hughes (M), who received the Harry Diamond Memorial Award, is section head at the Naval Research Laboratory, Washington, D.C., where he has worked since 1960. During the early 1960s, he discovered the vulnerability of MOS devices to ionizing radiation. Since then he has worked to find techniques to ameliorate these deleterious effects in succeeding generations of MOS integrated circuits. His present radiation-hardening efforts are focused on submicrometer silicon-on-insulator technologies. He is exploring new techniques for hardening separation by the implantation of oxygen (Simox) and bonded and etched-back silicon on insulator (Besoi) structures.

Gilbert F. Amelio (F), who received the Masaru Ibuka Consumer Electronics Award, is president and chief executive officer of National Semiconductor Corp., Santa Clara, Calif. His co-invention of the industry's first charge-coupled device in 1969 made possible solid-state image sensing and signal processing. He was instrumental in the development of area image sensors, the linear image sensors, and very-low-light-level video cameras.

John R. Dunki-Jacobs (LF), who received the Richard Harold Kaufmann Award, retired from General Electric Co., Schenectady, N.Y., in 1984 after 30 years with the company. He then established Industrial Power Systems Inc., now located in Lynden, Wash. He was responsible for the installation of the first industrial application of a 43-km, 35-kV submarine cable serving an offshore platform in the Persian Gulf. In 1967 he piloted the development of the first GE digital short-circuit program for industrial systems. A year later he pioneered a complex digital computer program to coordinate overcurrent protective devices.


Andy Schenk

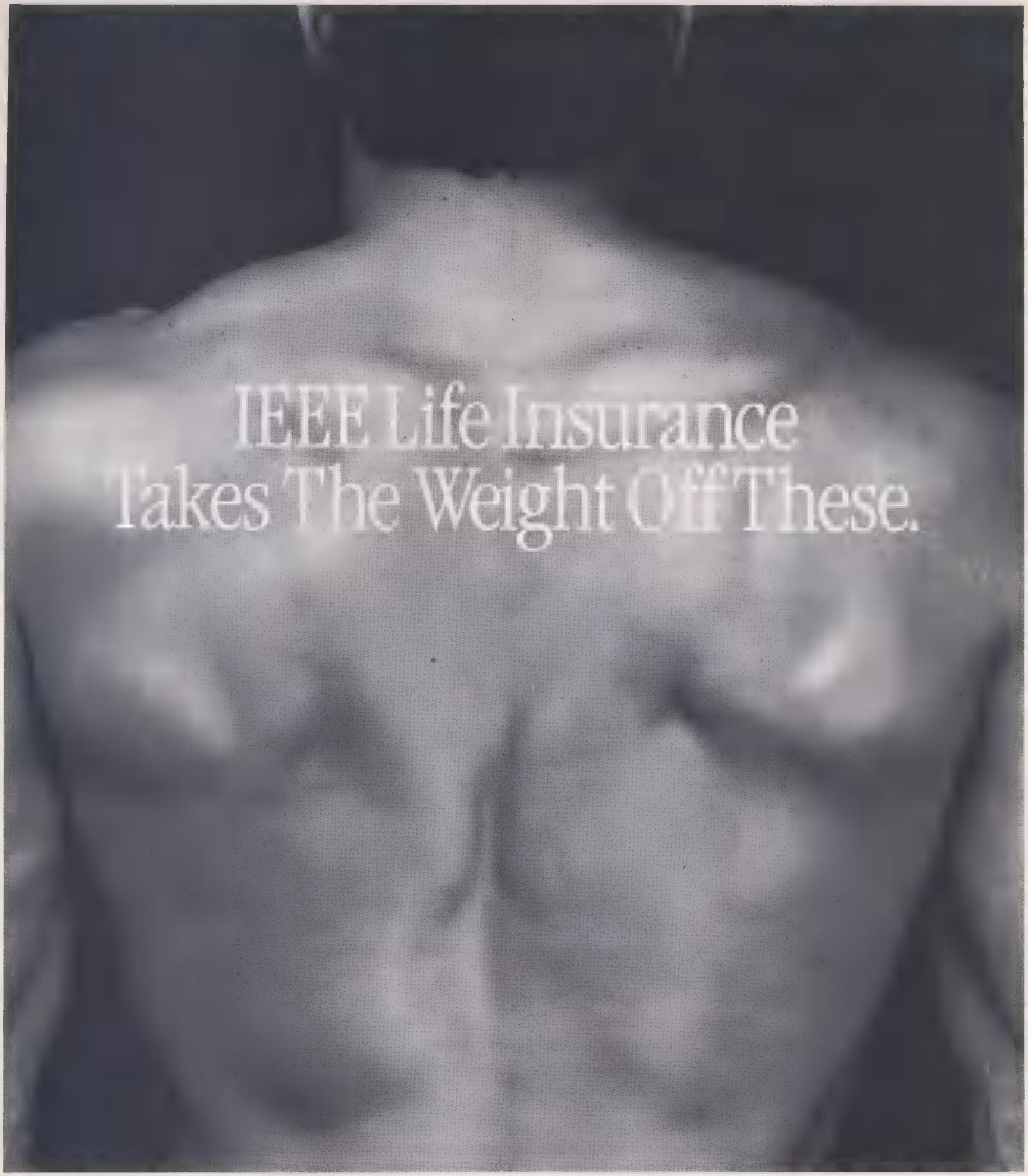
Morton B. Panish (F), who received the Morris N. Liebmann Memorial Award, is a member of the technical staff at AT&T Bell Laboratories, Murray Hill, N.J. In 1970 Panish and Izuo Hayashi presented the first experimental evidence for 300-K continuous wave operation of a (heterostructure) injection laser. In the 1970s he emphasized liquid phase epitaxy, but in 1978 he began an approach to molecular beam epitaxy that would permit the growth of complex InP-based heterostructures. By 1980 he succeeded in demonstrating that molecular beam epitaxy could be achieved with nonelemental sources.

Tak H. Ning (F) and **Hwa N. Yu** (F), who received the Jack A. Morton Award, are both employed at the IBM Thomas J. Watson Research Center, Yorktown Heights, N.Y. Ning is manager, very large-scale integration (VLSI) design and technology; Yu is program manager, silicon technology. Together they invented, demonstrated, and published the most advanced polysilicon self-aligned bipolar device structure, which has since become the industry standard for high-speed bipolar technology. Ning is also a co-inventor of the substrate-plate trench-capacitor dynamic RAM cell used in IBM's 4M- and 16M-bit chips. In the early 1070s, Yu pioneered and directed the development and demonstration of a one-micrometer VLSI Mosfet technology, a logic and array test vehicle (LATV) that was widely recognized and acknowledged as one of the most important contributions to the semiconductor industry as a forerunner for micrometer and submicrometer VLSI Mosfets.

Leslie J. Deutsch (M), who received the Judith A. Resnik Award, is manager of telecommunications and data acquisition technology development at the Jet Propulsion Laboratory (JPL), California Institute of Technology, Pasadena. In this role, he is responsible for all research and development for the National Aeronautics and Space Administration's (NASA's) deep space tracking network. At JPL he investigated the performance and feasibility of new error-correcting codes for use on future deep space missions for the NASA. He also developed algorithms for combining telemetry signals from deep space at multiple ground tracking facilities, thus helping to ensure the continued tracking of the Voyager 2 mission to Neptune.

Federico Capasso (F), who received the David Sarnoff Award, is head of the quantum phenomena and device research department for AT&T Bell Laboratories, Murray Hill, N.J. His seminal work on band gap engineering of semiconductor devices has opened up important new areas of research in electronics and optoelectronics. He invented new multilayer avalanche photodiodes for low-noise detection, the first solid-state photomultiplier, and new superlattice photoconductors. He also demonstrated a new depletion scheme capable of yielding ultralow capacitance independent of the device area and doping. He and his co-workers also made important contributions in the area of heterojunction bipolar transistors.

Jack M. Sipress (F), who received the IEEE Award in International Communication, is director of R&D and manufacturing for AT&T International Communication Services Submarine Systems, and director, Undersea Systems Laboratory for AT&T Bell Laboratories, Holmdel, N.J. At Bell Labs he is responsible for the development and manufacture of submarine cable communication facilities and associated technology. His technical leadership in the 1980s helped to spur the development and implementation of lightwave systems that were installed in 1988 to span the Atlantic and Pacific. ◆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4	13	22	31	40	49	58	67	76	85	94	103	112	121	130	139	148	157	166	175
5	14	23	32	41	50	59	68	77	86	95	104	113	122	131	140	149	158	167	176
6	15	24	33	42	51	60	69	78	87	96	105	114	123	132	141	150	159	168	177
7	16	25	34	43	52	61	70	79	88	97	106	115	124	133	142	151	160	169	178
8	17	26	35	44	53	62	71	80	89	98	107	116	125	134	143	152	161	170	179
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Programming the OS/2 Kernel. *Godfrey, J. Terry,* Prentice-Hall, Englewood Cliffs, N.J., 1991, 336 pp., $43.33.

A Practical Guide to Neural Nets. *Nelson, Marilyn McCord,* and *Illingworth, W.T.,* Addison-Wesley, Reading, Mass., 1991, 344 pp., $35.50.

Logic IC Master Reference. *Heiserman, David L.,* Academic Press, Troy, Mo., 1991, 735 pp., $149.95.

Microsoft Quickbasic Primer Plus. *Prata, Stephen,* and *Henderson, Harry,* Microsoft Press, La Vergne, Tenn., 1990, 608 pp., $24.95.

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Kodak

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COORDINATOR: George Likourezos
CONSULTANT: Paul A.T. Wolfgang, Boeing Helicopters

Software reviews

Probing neural networks

by Bruce Haner

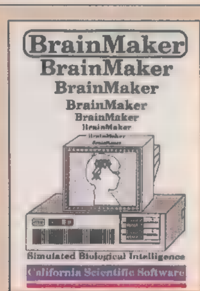
BrainMaker Professional allows users to train, test, and run neural networks. Its attraction is its great flexibility and many advanced features.

For one, the user can specify learning rates and training and testing tolerances. Others are several activation functions, including Gaussian, as well as a smoothing capability and a limited form of batching.

Additionally, BrainMaker Professional will automatically test and save the network at user-specified intervals during training. It also compiles extensive statistical files during both training and testing. The combination of these features is useful in determining whether the network has overtrained, causing it to cease working effectively with general data. If that happens, an earlier version of the network can be restored.

The software contains extensive display capabilities for numbers, pictures, bar charts, and symbols. I did find, however, that defining the display formats was awkward and involved a degree of trial and error. The good news is that simple displays adequate for most uses are automatically created.

BrainMaker Professional. *California Scientific Software. Software for designing, training, testing, and running neural networks. IBM PC or compatible or PS/2 or compatible with 512K memory; PC/DOS or MS/DOS 3.0 or higher; one floppy drive and any hard disk. US $795.*



BrainMaker Professional also offers two forms of sensitivity analysis. The first permits the user to select one output for a particular test case; then the software slightly varies each of the inputs one after the other to determine the impact on the output. The second method plots the impact of varying one input on up to four outputs.

One noteworthy feature lets the system begin with a few processing elements—the basic building blocks of a neural network—and then dynamically add new ones according to user-defined parameters. Another option allows the automatic elimination of unimportant connections between processing elements. Netmaker, a tool included in the package, prepares training and test-

Software reviews

ing files in a suitable format and provides extensive spreadsheet capabilities.

Brainmaker Professional has, alas, a very sloppy user interface and there are inadequate explanations in the user's guide and reference manual. However, I would recommend the package to anyone who needs a multifeatured back-propagation neural network. *Contact: California Scientific Software, 10141 Evening Star Dr., 6, Grass Valley, Calif. 95945-9051; 916-477-7481; fax, 916-477-8656; or* **circle 101.**

Bruce Haner has been involved since 1989 with neural networks at Security Pacific Automation Co.'s Artificial Intelligence Technology Group, Glendale, Calif.

For math and management

by David R. Hertling

We engineers like doing calculations and designs our own way. EEpal is a programmable desktop tool that accommodates us with an easy-to-use, interactive environment.

The package can be operated either as a stand-alone or a memory-resident pop-up program. It allows the user to look up engineering data, make mathematical calculations, and edit text files. It also provides calendars, alarms, and telephone autodial.

A truly standout feature is EEpal's ability to do complex arithmetic and provide complex mathematical functions. EEpal also displays a variety of screens.

A formula screen allows the user to input values (independent variables) and then simultaneously EEpal displays the calculated outputs (dependent variables). A minisheet screen is similar to a formula screen except that the inputs and outputs are columns of data. When lots of data are required by a screen, EEpal can read Ascii files.

A data screen is a simplified database, which may contain such data as resistor color codes or rectangular waveguide standards (both provided). EEpal comes with many data screens containing useful engineering data; these screens can be searched by fields. A help screen is provided for every built-in screen. All of the screens, including help screens, can be user-defined with a built-in program, EEmanager.

EEpal, at US $479, is suitable for IBM PC, XT, AT, 386, 486 PS/2, or compatibles. It requires a 384K memory, a hard drive with at least 2 megabytes, black-and-white or color monitor, and DOS 3.0 or later. A mouse is optional. *Contact: Eagleware Corp., 1750 Mountain Glen, Stone Mountain, Ga. 30087; 404-939-0156; or* **circle 102.**

David R. Hertling (SM) is a professor of electrical engineering at the Georgia Institute of Technology, Atlanta, Ga. His main teaching and research areas are RF and microwave circuits and devices.

COORDINATOR: Gadi Kaplan

Faults & failures

TCAS sees ghosts

A system that warns pilots of impending midair collisions is finally, after 30 years in development, being installed in the U.S. airline fleet. The system, called TCAS for traffic alert and collision avoidance system, sends a stream of interrogation signals to the same equipment aboard nearby aircraft and from their responses determines the planes' altitude, distance, and approach rate.

Plans call for all 4000 large aircraft in the United States to carry US $150 000 TCASs by the end of 1993. But the phase-in suffered a short-lived—and embarrassing—setback on May 2, when the Federal Aviation Administration (FAA) ordered a shutdown of 200 of the 700 units that had been installed. The 200 systems were seeing phantom aircraft and instructing pilots to evade planes that simply were not there.

The cause was quickly identified as a software glitch. More precisely, it was a software gap—five lines of code missing from the faulty units.

Not subject to the problem were TCASs manufactured by the Bendix/King Division of Allied Signal Inc., Baltimore, Md., and Honeywell Inc., Phoenix, Ariz. These were allowed to continue in service.

However, TCASs made by Collins Defense Communications Division of Rockwell International Corp., Dallas, were recalled so that the software could be fixed. The fix was simple: the units were reloaded with the correct program.

The problem arose in the course of testing, because Collins engineers had temporarily disabled the program's range correlation function—a few brief lines that compare a transponder's current response with previous ones and discard any intended for other aircraft. Without this filter, the system can misinterpret a response as coming from a fast-approaching airplane.

After testing the systems, Collins shipped them to airline customers without re-enabling the range correlation. For the most part, the systems worked as intended. But in high-traffic areas where many airplanes are interrogating each other—around Chicago, Dallas, and Los Angeles, particularly—ghosts appeared frequently. Pilots were misled, and air traffic controllers were distracted from their routine tasks by the need to handle nonexistent situations.

"A pilot would see the ghost image shoot across the screen because the on-board system was accepting all the replies as other TCAS airplanes in the vicinity interrogated the same TCAS transponder," Thomas Williamson, TCAS program manager with the FAA in Washington, D.C., told *IEEE Spectrum*.

TCAS II, the system currently being installed, tells pilots to climb, dive, or maintain the same altitude to avoid a collision. It also displays nearby planes on a small screen. The system was first demonstrated in the early 1970s, but making it work reliably was difficult because of interference by overlapping signals from multiple aircraft in crowded areas. The interference was eliminated by using directional antennas and variable-strength interrogation signals and developing range-correlation software to eliminate multiple responses.

In the range correlation scheme, the system notes the distance at which it first receives a response from another aircraft—say 10 miles. At the next interrogation, the distance may be 9.5 miles. The system would then expect the next response to be at approximately 9 miles, and would set a range gate so that it could look for a signal at that distance and calculate the closure rate. Without this correlation, the system becomes confused.

The FAA emphasized that the software fault did not pose a hazard. TCAS is a backup system; primary responsibility for avoiding midair collisions still remains with the ground-based air traffic control systems. Moreover, the FAA pointed out that TCAS has proved its worth in more than 1 million hours of operation.

"Had the problem involved TCAS software on a generic basis, then we would really be concerned," Williamson said. "But it was a breakdown in the quality control procedures of a specific manufacturer."

For its part, Collins has promised customers that it will correct all 200 systems within 90 days after discovery of the problem. "We'll be fully operational across the board well within that time frame," said Charles Wahag, Collins' manager of TCAS products.

Wahag defends Collins' quality control procedures, which were approved by a team of FAA software experts. "We had a simple human error where an engineer misclassified the changes in the software," he told *Spectrum*. "It didn't show up in our testing because one of the essential elements was absent: you have to have many, many TCAS-equipped airplanes in the sky," as in the high-traffic-density areas where the ghost problem appeared.

To prevent similar omissions, Collins now requires that a committee of software engineers review changes before a program is released. "More than one pair of eyes must review these things and make a decision," Wahag said.

COORDINATOR: George F. Watson
CONSULTANT: Robert Thomas, Rome Laboratory

CLASSIFIED EMPLOYMENT OPPORTUNITIES

The following listings of interest to IEEE members have been placed by educational, government, and industrial organizations [redacted] well as by individuals seeking positions. To respond, apply in writing to the address given or to the box number listed in care of *Spectrum* Magazine, Classified Employment Opportunities Department, 345 E. 47th St., New York, N.Y. 10017.

ADVERTISING RATES

Positions open—$34.00 per line, not agency-commissionable

Positions wanted—$34.00 per line, a 50% discount for IEEE members who supply their membership numbers with advertising copy

All classified advertising copy must be received by the 25th of month, two months preceding date of issue. No telephone orders accepted. For further information contact Theresa Fitzpatrick, 212-705-7578.

IEEE encourages employers to offer salaries that are competitive, but occasionally a salary may be offered that is significantly below currently acceptable levels. In such cases the reader may wish to inquire of the employer whether extenuating circumstances apply.

Academic Positions Open

Eurecom Graduate school in Communications Systems. Recruitment of Professors. The Swiss Federal Institute of Technology (EPFL) and the Ecole Nationale Superieure des Telecommunications (TELECOM Paris) organize jointly a new teaching and research institution, which will be located in Sophia Antipolis, [redacted] science and technology park hosting more than 500 hightech companies, at [redacted] short distance from Nice. Research will be developed in fields related to communication networks, e.g., image, speech and written communication; man machine interaction; mobile communications; real time industrial and high speed local area networks; computer networks; value added and integrated telematic services; management and security of communication systems. The candidates should have a Ph.D. degree and expertise in [redacted] of these fields. They will lead [redacted] research team and work in cooperation with the industry. Lectures will be given either in French or in English. The candidates should send a letter of application, a list of publications, [redacted] research proposal, [redacted] resume and the names of four references at the following address: CICA—EURECOM—Sophia Antipolis—BP 2229 -06560 Valbonne—France.

Washington University seeks qualified candidates for the position of Professor and Chair of the Department of Systems Science and Mathematics, with [redacted] desired starting date of July 1, 1992. We [redacted] interested in outstanding candidates with a strong research record, with a dedication to excellence in undergraduate and graduate education and with [redacted] demonstrated potential for administration and leadership. Washington University has a long standing commitment to the principle that all candidates should be afforded equal opportunity regardless of age, race, [redacted] or physical disability. Candidates must send a curriculum vitae and a list of references to: Professor C.I. Byrnes, Search Committee for the Systems Science and Mathematics Chair, Campus Box 1040, Washington University, One Brookings Drive, St. Louis, MO 63130.

The Department of Electrical Engineering at Colorado State University is seeking candidates for the Rockwell Optoelectronics Faculty position. This [redacted] position will be supported by industry, private endowments, and the University. The position will be a tenured or tenure-track appointment within the Department. We anticipate that the appointment will be for an individual who has recently established [redacted] outstanding record of research accomplishments in optoelectronics or a new graduate who shows exceptional promise. Candidates [redacted] sought in the areas of optoelectronic semiconductor materials and devices and in optoelectronic systems, with emphasis [redacted] practical implementation of telecommunication or optical computing systems. The position will be affiliated with the Center for Optoelectronic Computing Systems (an NSF Engineering Research Center jointly operated with the University of Colorado [redacted] Boulder). The new faculty member is expected to develop a major research program both through interaction with the existing programs in optical and electronic materials and devices as well [redacted] by development of new areas. Applicants should have an earned Ph.D., demonstrated research ability, and [redacted] strong interest in undergraduate and graduate teaching. Applicants should submit [redacted] detailed resume with a statement of their professional interests and goals, along with the [redacted] of three references. Applications will be accepted until August 31, 1991. This deadline may be extended if suitable candidates are not found. Additional information describing the applicant's work, such as papers or technical reports [redacted] welcomed. Please send all application materials to: Professor Jorge I. Aunon, Department of Electrical Engineering, Colorado State University, Fort Collins, CO 80523. (303) 491-6600 Fax (303) 491-2249, Email: aunon@longs.lance.colostate.edu. Colorado State is an EEO/AA employer. Office: 314 Student Services Building.

University of Illinois at Urbana-Champaign. Applications and nominations are invited for the Grainger Professorship in Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign. The Grainger Professorship has been endowed by The Grainger Foundation, Inc. in honor of Mr. W.W. Grainger who graduated from the College of Engineering in 1919. The appointment will be at the rank of professor with tenure in the Department of Electrical and Computer Engineering. The department solicits applications from distinguished senior engineers with expertise and research interests in any of the following or related areas: power systems, manufacturing, robotics, intelligent systems, control systems, and rotating machinery. Applicants must have an earned Ph.D., outstanding qualifications, and an ability to teach effectively at both the graduate and undergraduate levels. Selected candidates will be expected to initiate and carry out independent research and to perform academic duties associated with our B.S., M.S., and Ph.D. programs. Starting date is negotiable. Salary open, based on qualifications. Send resume, with references and a list of publications to: Professor Chester S. Gardner, Chair, Grainger Professorship Search Committee, University of Illinois, Department of Electrical and Computer Engineering, 1406 W. Green Street, Urbana, IL 61801. (217) 333-2300 The deadline for receipt of application materials to receive full consideration is September 15, 1991. The University of Illinois is an Affirmative Action, Equal Opportunity Employer.

The Department of Systems Design Engineering at the University of Waterloo is seeking applicants for tenure-track positions preferably at the rank of Assistant Professor, to begin employment during 1991-1992 period. The department is interdisciplinary with a diverse range of teaching and research activities which include human systems, societal and environmental systems, systems modelling analysis and design, and intelligent systems. The applicants should have a Ph.D. in Engineering and research interests in one or more of the following fields: 1) Engineering Systems Theory with emphasis in one or more of the following areas: control systems, intelligent systems, modelling and simulation, or system integration and design; 2) Societal and Environmental Systems with emphasis in one or more of the following areas: stochastic and statistical modelling and analysis, optimization, resource allocation, or decision analysis; 3) Environmental System Engineering with emphasis in one or more of the following areas: energy and resource systems modelling and analysis, risk and reliability analysis, environmental impact, or policy development; experience in engineering applications and design is highly desirable. The successful applicants will be expected to teach basic courses in the engineering sciences and mathematics as well as senior level and graduate courses in areas of expertise. Applications with complete curriculum vitae and the names of three references should be sent to Professor M. Chandrashekar, Chairman, Department of Systems Design Engineering, University of Waterloo, Waterloo, Ontario, Canada, N2L 3G1. In accordance with Canadian Immigration requirements, this advertisement is directed to Canadian citizens and permanent residents. The University of Waterloo encourages applications from qualified women and men, members of visible minorities, aboriginal peoples, and persons with disabilities.

Post-Doctoral Fellow: The Communication Sciences Laboratory at Simon Fraser University in Greater Vancouver has a post-doctoral opening for research in combined speech and channel coding for digital mobile communications. Candidates should have extensive research experience in at least one of the following areas: speech coding, channel coding and modulation, and mobile communications. The appointment is for one year and [redacted] be renewed for another year. The annual salary is in the neighborhood of CDN $25,000. To apply, please send [redacted] resume, with names and addresses of three referees, to Dr. Paul Ho, School of Engineering Science, Simon Fraser University, Burnaby, B.C., Canada V5A 1S6.

The University of Saskatchewan invites applications for a tenure track position in the Department of Electrical Engineering. Appointments are normally made at the Assistant Professor level. The candidate will join the Communications Research Group and will work with NSERC Chair in Communications. Preference will be given to candidates in the field of digital communication with specialization in RF, Microwave or Optical circuits/systems. Alternatively, candidates in coding, modulation or equalization theory for communication channels will be considered. Applicants must hold an earned Ph.D. degree and have demonstrated potential for teaching at the undergraduate and graduate levels and for developing [redacted] independent research program. The Department offers programs leading to B.E., M.Eng., M.Sc., and Ph.D. degrees. There [redacted] approximately 150 undergraduate and 60 graduate students in the Department and excellent research facilities. Curriculum vitae, a list of three referees and a statement of research interest should be addressed to: Dr. M.S. Sachdev, Head, Department of Electrical Engineering, University of Saskatchewan, Saskatoon, Canada, S7N 0W0. Applications must be received by September 30, 1991. The expected appointment date is January 1, 1992. In accordance with Canada Immigration regulations, this advertisement is directed in the first instance to Canadians, but other qualified candidates [redacted] also encouraged to apply.

Chair, Electrical Engineering: Must possess Ph.D. in Electrical Engineering with teaching experience at associate or full professor level. Responsiveness to student needs and good communications skills [redacted] essential. Other desirable qualifications include administrative, research, industrial experience, and professional registration. Requires strong commitment to teaching excellence, recruitment of students, and improvement of the program. Review of applications will begin in August 1991 and continue until position is filled. Effective January 1, 1992—August 15, 1992. Send letter of application, resume, and transcripts from colleges attended to: Personnel Director, West Virginia Institute of Technology, Montgomery, WV 25136. AA/EOE

Post-Doctoral Position, Magnetic Resonance Imaging. The Department of Radiology at the University of Minnesota is seeking an individual to carry out projects in reconstruction and processing of NMR spectroscopic imaging data as well as magnetic resonance imaging data. Applicants should have a Ph.D. in physics, medical physics, electrical engineering or other related field. Experience with C [redacted] Unix is

CLASSIFIED EMPLOYMENT OPPORTUNITIES

preferred. Previous exposure to magnetic resonance imaging is desirable. Equipment includes a 1.5 Tesla Siemens scanner, a 4.0 Tesla research human scanner, a 4.7 Tesla animal unit, a Kontron image computer, and several Sun Sparcstations. In addition, access to supercomputers is also available. The position is for two years, starting sometime after July 1, 1991. Salary is commensurate with experience. Interested individual should contact Dr. Xiaoping Hu, Department of Radiology, Box 292 UMHC, Harvard at East River Street, Minneapolis, MN 55455. The University of Minnesota is an equal opportunity educator and employer.

University of California at Berkeley Department of Nuclear Engineering, invites applicants for [redacted] tenure-track assistant professor position in any one of four fields: Nuclear Materials, Nuclear Thermal Hydraulics, Reactor Theory and Computation, or Fusion. Desirable areas of expertise in these fields include respectively, irradiation effects in metals; thermal science applications to reactor safety; particle transport, reactor control dynamics, and neutronics; and fusion reactor engineering and applied plasma physics. The successful candidate will be responsible for teaching undergraduate and graduate courses in the department, and must show potential for high quality research. A doctoral degree in [redacted] appropriate field is required. The position is available July 1, 1992. Interested persons should apply by November 1, 1991 to: Dr. T. Kenneth Fowler, Chair; University of California, Berkeley; Department of Nuclear Engineering; 4153 Etcheverry Hall; Berkeley, California 94720. The University of California is an Equal Opportunity, Affirmative Action Employer.

Auburn University, Earle C. Williams Eminent Scholar Chair in Electrical Engineering. Nominations and applications are invited for the Earle C. Williams Eminent Scholar Chair in Electrical Engineering. Candidates for this chair should have achieved national and international prominence in digital systems and/or microelectronics. Applicants or nominees must have an earned doctorate, senior academic experience, and a documented record of distinction in university teaching and research. The successful candidate will be expected to provide intellectual leadership in his/her [redacted] of expertise for the Department of Electrical Engineering as well as enrich the scholarly environment at Auburn University. Auburn University is located in the city of Auburn in east-central Alabama. This land-grant university enrolls more than 21,000 students, the largest on-campus enrollment in the state. The Department of Electrical Engineering, one of eight departments within the College of Engineering, offers Bachelor, Master, Master of Science and Ph.D. degrees in Electrical Engineering. The department has [redacted] current enrollment of 939 undergraduate students and 100 graduate students. The 28 full-time faculty have an annual research expenditure of approximately $2 million. The Search Committee will begin its review of applications immediately. Interested candidates should submit: (1) a detailed resume, (2) a letter indicating an interest in the chair, the candidates's academic philosophy, and a brief statement of accomplishments in teaching and research, and (3) names and addresses of five references. Nominations should be submitted with the complete name, mailing address and telephone number of the individual nominated. Applications and nominations should be sent to Professor J. David Irwin, Department of Electrical Engineering, Auburn University, AL 36849-5201. Auburn University is an affirmative action/equal opportunity employer. Applications from minority and female candidates are encouraged.

Trinity College, one of the few highly selective liberal arts colleges awarding degrees in engineering, seeks applicants for a tenure-track assistant professorship in Mechanical Engineering. Employment will start in the fall of 1992. Candidates must hold [redacted] Ph.D. in Mechanical Engineering with primary expertise in thermodynamics and heat transfer. A successful candidate will be committed to teaching engineering within a liberal arts setting and to offering courses for non-science majors on a regular basis. Trinity offers a standard curriculum in Mechanical Engineering and provides laboratories for research and instruction. The department is located in [redacted] new Mathematics, Computing, and Engineering Center that houses laboratories for instruction and research in solid state electronics, integrated circuit design, solid mechanics, materials science, fluid mechanics, and electrophysiology. Computing resources include Macintosh and PC-compatible microcomputers; SUN, Apollo, and DEC workstations; and VAX mini/mainframes. These computers are networked through an Ethernet LAN and connected worldwide to the Internet. Candidates must send a curriculum vita, a statement of teaching and research objectives, copies of published articles, and the names of three people willing to write letters of recommendation to Dr. David J. Ahlgren, Chair, Department of Engineering and Computer Science, Trinity College, Hartford, CT 06106. We especially seek applications from women and members of minority groups. Applications will be accepted until January 10, 1992. Trinity College is an AA/EO employer.

Faculty Position—Bradley University: The Search Committee of the Department of Electrical and Computer Engineering and Technology invites applications for [redacted] tenure-track faculty position in the [redacted] of electronics and/or digital systems. Candidates should have [redacted] Ph.D. in Electrical or Computer Engineering and [redacted] strong interest in undergraduate engineering education. Industrial experience is preferred. The successful candidate will be expected to teach in the electrical engineering undergraduate and graduate programs [redacted] well as the undergraduate electrical engineering technology program, serve [redacted] project advisor to EE seniors and graduate students, and to do appropriate research as documented by publications. A January, 1992 starting date is preferred, though qualified candidates requesting an August, 1992 starting date will also be considered. Appointment will be at the assistant or associate professor level. Candidates should send [redacted] complete resume, including [redacted] statement of teaching and research interests, and the names of three references to Dr. Brian D. Huggins, Department of Electrical and Computer Engineering and Technology, Bradley University, Peoria, IL 61625. To assure full consideration, application materials should be received by October 15, 1991. Bradley University is an Equal Opportunity, Affirmative Action employer.

Wayne State University anticipates openings for visiting, or tenure-track faculty in the Electrical and Computer Engineering Department. We are seeking research oriented individuals interested in computer engineering, with emphasis on networks, parallel and distributed processing, modeling and performance analysis or in VLSI design. Applicants should have an earned Ph.D. and be committed to teaching and research. Rank and salary will depend on experience and qualifications. Wayne State is [redacted] large urban university, and welcomes applications from women and minorities. Resumes should be sent to Dr. M.P. Polis, Chair, ECE Dept., Wayne State University, Detroit, MI 48202. Wayne State University is [redacted] Equal Opportunity/Affirmative Action employer.

Research Scientist needed in Seattle, WA. to develop methodologies and applications to measure and analyze the acoustic and psychoacoustic properties of the human hearing system including: generation, high speed real-time presentation, acquisition, and analysis of acoustic signals with digital signal processing techniques to measure the acoustic properties of human external, middle, and inner ear; analysis of subject responses to acoustic signals using adaptive psychoacoustic procedures; design and implementation of massively parallel systolic cellular logic processor for digital signal processing in hearing research; design, simulation, and layout of very-large-scale integrated circuit chip with multiple processors for systolic cellular logic; development of parallel algorithms for systolic cellular architectures for digital signal processing in hearing research. Requires M.S. degree in Computer Science and 2 years of experience which includes 1 year experience in developing applications to measure the acoustic properties of the human hearing system, 6 months experience in the design and implementation of massively parallel processor, and 6 months experience in the design of very-large-scale integrated circuit chip. 40 hours work week. $3,491 per month. Must have proof of legal authority to work in the United States. Send resumes by Sept. 1, 1991 to Employment Security Department, Employment Service Division, Attention: JOB# 253694-L, Olympia, WA.

The University of New Mexico is seeking candidates for the position of Research Professor and Director, Alliance for Photonic Technology. This is an administrative position reporting directly to the Vice President for Research. The Alliance for Photonic Technology (APT) has been formed by the University of New Mexico's Center for High Technology Materials (CHTM), Sandia National Laboratories, Los Alamos National Laboratory and the Air Force's Phillips Laboratory (the R&D participants) for the purpose of enhancing U.S. Industrial competitiveness by assisting these laboratories in technology transfer in selected areas of photonics and opto-electronic technology. The University of New Mexico has been designated as the lead R&D participant and serves as APT's host. The Director is responsible for all aspects of APT's day-to-day operations, including: Photonic technology assessment, with an emphasis on matching the needs of industry to the capabilities of the R&D participants; interaction with customer companies and potential customer companies, including the technical coordination of joint development programs with the R&D participants and oversight of APT's administrative office. This position is highly visible and to enhance the credibility of the effort the Director should have achieved national recognition in photonics technology with an advanced degree in [redacted] relevant technical specialty. The ideal candidate will have experience in the industrial, government and academic sectors, with the demonstrated interpersonal skills essential to building a network of contacts across this entire spectrum. U.S. citizenship is required. Applicants should submit a detailed resume by September 1, 1991, with [redacted] statement of qualifications and the names of three references to: Prof. J.H. Mullins, Chairman, APT Search Committee, University of New Mexico, Farris Engineering Center, Room 157, Albuquerque, NM 87131.

Research Associate—Electrical Engineering-Systems. Research in the area of linearly-constrained adaptive filtering and beamforming. Develop new algorithms in linearly-constrained adaptive arrays. Collect and analyze data, prepare reports for publication. Req: Ph.D. in Electrical Engineering; graduate level coursework in antenna array processing and adaptive methods; research background in mapping signal processing algorithms onto VLSI implementations; strong background in mathematics and optimization algorithms; knowledge and skill in the use of MatLab and UNIX systems. Sal: $576.92/wk; 40 hrs/wk. Job/Interview site: Los Angeles, CA. Send this ad and a resume to Job #ET3172, P.O. Box 9560, Sacramento, CA 95823-0560 no later than September 1, 1991.

Naval Postgraduate School, Monterey, California, ECE Department invites applications for tenure-track positions in the areas of Power Engineering and Radar/EW Systems. Candidates should hold a Ph.D. in Electrical Engineering or [redacted] closely related field and be capable of quality instruction and successful research, primarily with MSEE candidates. The department conducts a fully ABET-accredited graduate engineering program awarding MSEE, EE and Ph.D. degrees to military officers of the US and allied nations and DoD employees. Opportunities for sponsored research are available and extensive computational and laboratory facilities exist. Applicants should send a complete resume, a publication list, [redacted] statement of teaching and research interests, visa status, and the names and addresses of three references to Dr. Michael A. Morgan, Chairman, Electrical and Computer Engineering Department, Code EC,

Naval Postgraduate School, Monterey, CA 93943. Equal Opportunity, Affirmative Action Employer.

Government/Industry Positions Open

System Engineer for Computer Consulting Firm to work in Columbus, Ohio area. Design develop & test a real-time X.25 packet switching network system which provides network services for the telephone interexchange network. Responsibilities include interaction with system planners in generating system requirements and detail software design, developing test plans and executing these to ensure product meets criteria in service compatibility, system operability & real-time performance. Job also requires investigation and evaluating efforts of using C++ program language and Object-Oriented approach in developing new software modules. Support of the software development through verification and field implementation is also required. Requires Master's Degree in Electrical Engineering and 4 years direct experience in the job described. Or, 4 years related experience in highly reliable (fault tolerant) communication network system which include protocols & switching network applications; Plus training courses in Queueing Theory and Packet Switching Network. Experience may be gained before, during or after degree. Salary, $46,200/yr., 40 hrs/wk, no O.T., 8:30am-5pm, Mon-Fri. Must have proof of legal authority to work permanently in the U.S. Send resume in duplicate (no calls) to J. Davies, JO# 1260281, Ohio Bureau of Employment Services, PO Box 1618, Columbus, OH 43216.

Research Scientist, Chief. Conduct application-specific R&D and design of intelligent camcorder systems using fuzzy logic and neural network theories. Use methodologies of artificial intelligence/automatic control, psychology and decision analysis to design intelligent systems which can function autonomously and stimulate performance of human vision systems, especially in connection with learning control, neural networks and fuzzy logic-based control. Establish methodologies for developing fuzzy logic systems, assessing performance and exploring potential applications. Perform qualitative systems analysis based on fuzzy logic. Min. Ph.D. in EE or computer science and 2 yrs. exp. in fuzzy logic and neural networks, R&D plus academic work in areas of artificial intelligence, fuzzy logic and neural networks. Salary $64,000/yr. Job site and interview San Jose, CA. Send this ad and your resume to Job No. BLW-9210, P.O. Box 9560, Sacramento, CA 95823-0560, no later than August 31, 1991.

Senior Research Scientist: Conduct ind. res. & dev. in flight control sys. design, est. & guidance algorithm dev., comp. aided control sys. design, flight sim., adv. sys. & control res., model dev. & valid., & sys. integ. & prototype impl. Req. Ph.D. in Elec. Engr. & 1 yr. in job or 1 yr. as Consultant in Aircraft Engr. $4800/mo. Job-site/intvw: Chatsworth, CA. Send ad & resume to Job #MD21230, P.O. Box 9560, Sacramento, CA 95823-0560 no later than 9/1/91.

Engineer, Senior Research and Development. Ph.D. in Electrical Engineering, and 1 year experience in job offered or 1 year experience analog and digital circuit design and analysis, including microcontroller and I/O interface circuits, low-frequency and radio frequency circuits design, computer simulation, digital circuit system reliability analysis and experience or coursework in advanced computer architecture, digital computational techniques for electronic circuits, computational models and methods, lumped system theory, optimization methods, random variables, and artificial intelligence. To design, research and develop computerized physiological monitoring devices and biomedical sensors. $52,500/yr. Job/interview site: Redwood City, CA. Clip and send with resume no later than September 1st, 1991 to Job #PC20200, P.O. Box 9560, Sacramento, CA 95823-9560. Upon hire, must show immediate ability to work in the U.S.

Electrical Research Engineer/Development Staff Member -Position will focus on micromachining using high power Nd:Yag, CO2, & short-pulsed ultraviolet laser rays, & its applications for precision fabrication of magnetic data storage devices. Will provide technical advancement & leadership in: (1) Devel. of models based on applications of laser, ultrasonic, chemical & abrasive processing of ceramic, polymeric & composite materials; (2) Devel. of micro-machining techniques to refine & miniaturize all components of magnetic data storage devices; & (3) Characterization & non-destructive eval. of materials rel. to manufacturing of data storage devices, incl. appl. of state-of-the-art techniques of ultrasonic & thermal materials characterization. Will represent co. in international conferences rel. to above. Must publish results of orig. research in scholarly journals & internal tech. pubs. Reqs.: Ph.D. in Applied Physics & 5 yrs. in job offered or as Scientist, Applied Physics. Required experience to include: (A) Performing & supervising adv. research & devel. projects rel. to: (1) Optics & lasers, incl. excimer lasers, Nd:Yag lasers & CO2 lasers; (2) Materials science of polymers, composites, ceramics, alloys & metals; (3) Thermal properties of materials & thermal physics at interfaces; (4) Materials characterization & processing using optical, ultrasonic & other techniques; (B) Publication record in the above areas (min. 2 articles); & (C) Data acquisition & signal averaging, incl. interfacing PC to electronic equipment & motor controls. 40 hrs./wk.; $74,200/yr; Job & interview site: San Jose, CA. Send this ad and resume to Job #EG14161, P.O. Box 9560, Sacramento, CA 95823-0560 not later than August 30, 1991. EOE.

Software Design Engineer—Major Central New Jersey corporation seeks Software Design Engineer. Responsible for maintaining and further developing customized software for a UNIX-based customer presentation system. Hardware includes AT&T 3B2 that controls optical disk players/recorders, video switches, tape devices, computer graphic workstations, and various interface devices. M.S. in computer science or electrical engineering or equivalent experience. Minimum five years software development experience in UNIX/C and MS-DOS environments at the device driver level. Must be a self-starter with a special interest and competence in interactive video and graphics presentation systems. Salary range $50K to $75K. Send resume to P.O. Box 1114, Bedminster, N.J. 07921.

Software Engineer for firm in NE Ohio. Design, implement, & develop software for a Computed Tomography system (x-ray body scanner). Specifically, the engineer will work on the Gantry Processor Unit, Scanner Interface Controller Unit, Central Processing Unit, & Networking Unit. This involves real-time motion control of the patient couch & x-ray frame, expert system development, data communication between the units, & networking. All work utilizes "C" & Motorola 68000 Assembly language under UNIX-like operating system, in a multiprocessor environment. Must have M.S. in Electrical Engineering & academic program must have included one course each in: Data Communication & Networks, Parallel Processing, Advanced (32 bit) Microcomputer Systems, Expert Systems, & Microprocessor Interfacing. Must have 6 mos experience [illegible] systems engineer (experience may be gained before, during, or after degree) & must be conversant with 32 bit microcomputer systems hardware; multiprocessing; & C & Assembly computer languages, as evidenced by academic letter(s) of reference, publications(s), &/or employer testimonials(s). 40 hrs/wk, 8am-5pm. $33,000/yr. Must have proof of legal authority to work permanently in U.S. Send resume and course transcript in duplicate (no calls) to J. Davies, JO# 1255724, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, Ohio 43216.

Manager of Engineering for gov't contractor company in central OH. Manages 8 staff engineers. Determines engineering priorities, schedules, planning. Develops and maintains administrative system in accordance with DCAAM 7640.01 Contract Audit Procedure. Prepares job costing information. Determines & acquires equipment, information, training & supplies for engineering staff. Maintains adequate level of technical abilities of engineers. Performs project engineering tasks: Designs high reliability electronic control systems & instrumentation. Prepares proposals for customers, performs research & development of prototypes for military testing, prepares production and testing procedures. No exp. required in above duties but applicants will qualify with MS in Electronic or Bio-Medical Eng. [illegible] 5 yrs. Electronics Eng. exp. in/with project mgmt, development of high reliability electronic equipment & programming in Assembly, Turbo Pascal languages & Data Base design. The 5 yrs. exp. must include 1 yr. acctg. exp. & 2 yrs. in foreign trade. 40 hrs/wk, 8am-5pm, Mon-Fri., $48,000/yr. Must have proof of legal authority to work permanently in U.S. Send resume in duplicate (no calls) to Jan Davies, JO# 1275866, Ohio Bureau of Employment Services, PO Box 1618, Columbus, OH 43216.

Computer Performance Architect/Analyst. Develop hardware & software tools to analyze & estimate microprocessor based system performance; characterize workloads for microprocessor based platform; define & determine DOS/Windows/UNIX characteristics; conduct performance & design tradeoffs for desktop [illegible] server platforms; develop hardware/software tracing environment for graphics based applications; test & evaluate compiler performance. Ph.D. in Electrical and/or Computer Engineering or Computer Science. Academic project/research background in VLSI processor design and layout in CMOS, high-speed VLSI CPU design, programmable logic array design, compiler development, instruction scheduling, 3-D graphics application to VLSI design and semiconductor inspection, UNIX kernal porting and integration, C, Fortran, X86 Assembler and DOS; academic coursework in computer architecture, digital computer design and engineering analysis. $4,500/mo.; 40 hrs./wk. Place of employment and interview: Santa Clara, CA. If offered employment, must show legal right to work. Send this ad and your resume to: Job No. SK2252, P.O. Box 9560, Sacramento, CA 95823-0560 not later than August 31, 1991. The company is an equal opportunity employer and fully supports affirmative action practices.

Engineering—Senior Process Engineer. Design & simulate sub-quarter micron CMOS devices & process; conduct test pattern mask set design, layout & procurement; develop process steps; fabricate, characterize, model & analyze devices; characterize, model & design advanced III-V compound devices; perform analytical characterization, novel process design & modeling of nonequilibrium behavior in scaled devices. Ph.D. in Electrical Engineering or Electrical Engineering and Computer Science. Academic project/research background in solid state device physics & technology, including MESFET silicon devices and GaAs device processing using IC fabrication equipment including diffusion furnace, patterning and thin film deposition; also silicon, GaAs device and material characterization using electrical & analytical characterization techniques including HP equipment, TEM and SEM, semiconductor process & device simulators including SUPREM and PISCES and computer programming in Basic, Fortran and C. $4,685/mo.; 40 hrs./wk. Place of employment and interview: Santa Clara, CA. If offered employment, must show legal right to work. Send this ad and your resume to: Job No. PM10318, P.O. Box 9560, Sacramento, CA 95823-0560 not later than August 31, 1991. The company is an equal opportunity employer and fully supports affirmative action practices.

Electrical Engineer needed by medium sized consulting engineering firm in Columbus, Ohio specializing in building design. Will design power distribution, lighting and special electrical systems for building, including academic buildings for lower, secondary and higher education, auditoriums, vehicle maintenance buildings, offices and computer centers, laboratories and hospitals. Will also coordinate work with construction contractors. Must have four-year bachelor's degree in electrical engineering and minimum 3 years experience in the duties described above. Forty hour work week, 7:30 a.m. to 5:30 p.m. Monday through Thursday, 7:30 to 11:30 a.m. on Fridays. Salary: $31,600 p.a. Applicants must have proof of legal authority to work permanently in the U.S. Send resumes in duplicate (no calls) to J. Davies,JO# 1260297,

(Continued on p. 63)

PROFESSIONAL CONSULTING SERVICES

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(Continued from p. 61)

Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, Ohio 43216.

Applications Physicist. 40 Hours per week (8:30 a.m. to 5:00 p.m.). $42,000 p.a. Research and development of a high-speed data acquisition and beam parameter processing system for a high-energy particle accelerator. Specification and integration of microprocessors, a real-time operating system and a system communication package to develop a novel, coherent and efficient system. Analysis of data obtained leading to enhancements in accelerator beam control techniques and performance. Applicants must have a Ph.D. in High Energy or Accelerator Physics and 3 years experience as a Research Physicist in High-Energy or accelerator Physics. Prior experience must include enhancement/reconfiguration of hardware and writing of high-level software for applications tailored to high-speed data acquisition, processing and analysis of sub-atomic particle interactions or particle accelerator performance. Must have proof of permanent legal authority to work in the U.S. Resumes should be sent to: Illinois Department of Employment Security, 401 South State Street—3 South, Chicago, IL 60605, Attn: L. Donegan, Ref# V-IL-2433-D. No Calls. An Employer Paid Ad.

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Scanning
The Institute

Dues to increase by $10

In part to offset years of inflation that have eroded the purchasing power of IEEE dues, the Board of Directors at its meeting in San Francisco in June approved an increase of US $10 in basic membership dues for all grades above Student, effective with the 1992 billing cycle. U.S. non-student members will pay an additional $2 assessment for United States Activities. Of the $10 increase, $4 will be used to offset an operating loss of $550 000 in the 1991 budget and a reduction of $800 000 in interest and dividend income. Curtailed operating expenses throughout the 1992 budget coupled with increased income from publication activities will result in an operating surplus designed to restore the financial health of the IEEE over the next four to six years.

To increase staff productivity, effective with the first pay period in 1992, the work schedule for the staff at the New York City, New Jersey, and United States Activities Washington, D.C., offices will be increased by one-half hour per day.

IEEE Standards Press debuts

The IEEE Standards Press has been established to respond to an industry demand for more standards information and to foster the positive influence that standards have in industry. Because essential standards-related information that would benefit industry often falls outside the scope of an IEEE Standard, Recommended Practice, or Guide, it is the charter of the new group to fill this information void and support the dissemination of standards information worldwide. For additional information, contact Deborah Czyz, managing editor, IEEE Standards Press, 445 Hoes Lane, Piscataway, N.J. 08855-1331; 908-562-3829.

USAB opposes U.S. space station

Leaders of the United States Activities component of the IEEE have called on the U.S. Senate to oppose a US $30 billion–$40 billion space station and instead support development of a scaled-back version costing less than $10 billion. According to Arvid G. Larson (F), chairman of IEEE-USA's Technology Policy Panel, full funding of the Space Station Freedom would require substantial cuts in National Aeronautics and Space Administration programs that have greater significance on U.S. competitiveness and quality of life issues.

Philadelphia to host candidates

The IEEE Philadelphia Section will hold its Second Annual IEEE Candidates Night on Aug. 20. Invitations have been issued to President-Elect candidates Wallace S. Read, Robert T.H. Alden, H. Troy Nagle, and Martha Sloan to discuss the issues. For further information, contact W.W. Middleton, 215-687-1482.

TAB Office opens in Brussels

A new Technical Activities Board office in Brussels, Belgium, provides publications and membership services to Europe, Africa, and the Middle East. By ordering books and conference records through the Brussels office, members in those localities can be confident of receiving them in about two weeks.

New CD-ROM products

The IEEE, the Institution of Electrical Engineers (IEE), and University Microfilms International have jointly announced agreement to produce IEEE/IEE Publications Ondisc (IPO). IPO provides photocopy-quality images of all periodicals and conferences published by the IEEE and the IEE since 1988. Access to articles is provided by the IEE's Inspec database of abstracts and indexing. For further information, call Jim Ashling at 908-562-5550.

Malcolm Baldrige Award video

The IEEE will present a live satellite videoconference, "Quality Management Approaches to the Malcolm Baldrige Award," on Sept. 19. Call Judy Brady at 908-562-3991.

Coming
in Spectrum

Gulf War technology. A new age of smart weaponry and high-tech warfare has been heralded by the war in the Persian Gulf. *IEEE Spectrum*'s report on the affair will discuss the impressive successes in C^3I, defense suppression, and precision-guided weapons. It will also analyze how such gear may be improved after its first battlefield test since the microelectronics revolution in weaponry.

Just as critical were the behind-the-scenes capabilities and technologies affecting logistics, maintenance, training, and simulation. *Spectrum*'s reporters will provide first-hand accounts of how high mission availability was maintained, how simulation and realistic training prepared U.S. troops for actual battle, and how industry support in the field sustained the massive effort. Television's ubiquitous and unprecedented role will be probed as well.

Finally, distinguished experts will look beyond the Gulf arena to assess how recent events there may reshape the next war and are already remolding national and regional defense industries.

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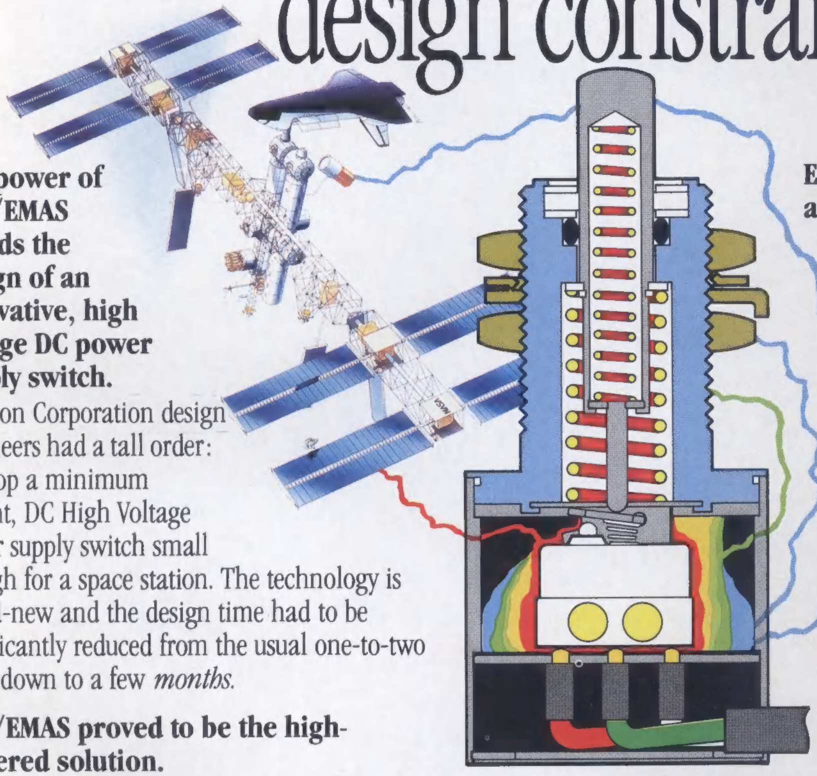
How EATON turned the power on when faced with severe design constraints.



The power of MSC/EMAS speeds the design of an innovative, high voltage DC power supply switch.

Eaton Corporation design engineers had a tall order: develop a minimum weight, DC High Voltage power supply switch small enough for a space station. The technology is brand-new and the design time had to be significantly reduced from the usual one-to-two years down to a few *months.*

MSC/EMAS proved to be the high-powered solution.

Eaton built finite element models of electromagnetic power switches. MSC/EMAS then calculated the magnetic flux distribution of each model under varying conditions. By altering the material characteristics, excitations and sizes, Eaton was able to "design" the model that met its parameters. When building and testing the actual switch, Eaton found the results matched MSC/EMAS model results to within 5%. Using MSC/EMAS eliminated the need for repetitive prototyping and testing. As a result, Eaton engineers cut normal design time by over 75%.

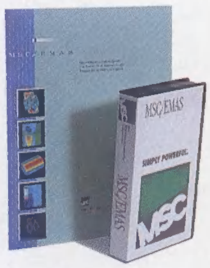
Electric and magnetic field problems are no problem for MSC/EMAS.

Electrical engineers use MSC/EMAS to solve electric and magnetic field problems involving linear, nonlinear and anisotropic materials. The program lets users analyze the entire range of electromagnetic behavior... from electrostatics and non-linear magnetostatics to eddy currents and wave propagation. What's more, these varied applications can be accurately simulated under one powerful, easy-to-use program.

MSC/EMAS is available on a variety of computer platforms, from engineering work-stations to supercomputers, and is backed by the most comprehensive support, training and documentation in the industry.

No wonder MSC/EMAS is the world's premier software package for electromagnetic analysis.

Current information on our concurrent family of products.



Apply MSC/EMAS to your company's toughest electromagnetic field problems. For videos or brochures on MSC/EMAS or any member of MSC's complete family of computer-aided engineering software, call us at (800) 336-4858 or (213) 258-9111. We'll help you turn the power on.

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